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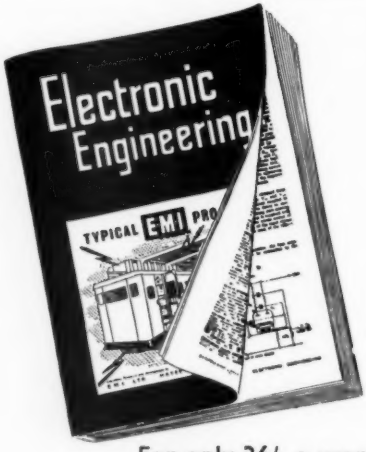

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Notes and Comments

Men at Work

The Ergonomics Research Society held its 11th Annual Conference in Cambridge in April. Ergonomics is the study of the total environmental conditions in which man works. Since there is interaction between man and his environment, it follows that the man himself is as much the object of the study as is the environment around him. It is not surprising then that members of the Society include doctors, engineers, psychologists and physiologists, besides others. The common bond between different members is their interest in research into the factors which together make for human efficiency at work and in the application of existing knowledge to this problem.

This conference was characterised by the topicality of the subjects under discussion. There were four main topics, discussion of each extending over at least half a day. For two of these—'Ergonomics in the Armed Forces' and 'Ergonomics in the Building Industry'—there was a balance between papers on research studies and those on its application. It was not surprising, perhaps, that most of the contributions from America were associated with problems of space travel, high-speed flying and such like. In the world of space travel, man will find himself operating in an environment in which he has little or no previous experience (that of weightlessness for example) and those concerned in problems of ergonomics are attempting to investigate how man is likely to react under such conditions.

American psychologists have now begun to gather a large amount of information and have developed equipment for recording physiological and psychological responses which is undoubtedly the envy of their English colleagues. Clearly, in a conference of this sort, it is only possible to see and hear that which is not restricted for security reasons, but there is enough that is available to provide plenty of material for discussion, and to indicate the importance of some of the problems immediately confronting high speed or rocket travellers.

Some of the current studies in the building industry seem to have their origins about half a century ago. Talor, Gilberth, Farmer and, more recently, Ann Shaw have all argued the merits of the study of time taken to perform a task versus the motion patterns employed. The studies described as being currently undertaken indicate that the building industry is concerned with these as well as with many of those other problems that now occupy the attention of psychologists in other industries, such as incentive payments and size of work gangs.

Members of the Cambridge Applied Psychology Research Unit are well known to the British Association's Section J (Psychology) and four of them presented papers on the highly topical field of vigilance. For the past fifteen years, the Cambridge Unit has produced a volume of experimental studies which have application in industry and in the forces. In the studies reported at this meeting, a relatively new feature has been introduced, namely the use of personality tests. This introduces a new and important element into the numerous vigilance studies which may be of the greatest significance to tasks of industrial and other inspection including that of monitoring.

Finally, a group of papers from Holland emphasised that growth of interest in ergonomics is taking place simultaneously in a number of countries, and demonstrated the value of the

international exchange of information between the various workers.

Although the Ergonomics Research Society's meetings demonstrate the need for scientists in allied fields to communicate with one another, and although much of the information presented by one scientist is readily understood by another in a different field, from time to time the fact emerges that the everyday terms of one discipline are unfamiliar or have a different meaning to the scientist in the allied field. For clear exchange of information it is imperative that we should continually make sure that we are intelligible to our audience. Only thus can we avoid the irritation that occurs when we listen but do not comprehend.

H. G. MAULE

Archaeological Field Experiments

This summer a new approach is to be made to the problems of archaeological excavation involving a complete reversal of the normal course of events. An 'earthwork' is to be erected in order that the progress of its denudation can be recorded exactly. A great many archaeological monuments are in some way variants of a mound and ditch, whether circular like a barrow, or extended like hill fort walls. A long ditch and bank is to be constructed by the British Association Research Committee on Archaeological Field Experiments. Because of the great aggregation of monuments on the chalk a downland site has been chosen. This is on Overton Down, part of the Fyfield Down Nature Reserve. A ditch 100 ft. long, 6 ft. deep and 12 ft. wide will be dug and the material from it heaped into a bank alongside. This bank will be built in layers, defined with templates, and clearly marked with coloured roadstone chippings. Vertical steel rods in the spine of the bank will be sunk to chalk bedrock and will form permanent datum points. Pottery markers will be incorporated in the bank and spread on the ground. With this model of a prehistoric earthwork, direct observations will be made on the effects of primary frost-weathering and silting of the ditch, settling and compaction of the bank, movement of soil, and disturbance of stratification. From this point onwards the main method of investigating the structure will be the familiar technique of cutting trenches and recording the developed profile. Of particular interest to archaeologists will be observations of the time at which the bank material starts to slide into the ditch despite the presence of a berm; the manner in which the soil moves; and the ultimate position of the pottery markers. The sequence of observations are planned to extend over 100 years.

In addition to these observations on structure the effect of burial on a variety of materials will be followed. Interest will be concentrated on organic materials, in particular bone, wood, charcoal, leather and textiles. In this aspect of the work, if primitive materials are to be successfully mimicked, special preparatory work will arise, as for example in the necessity to use only natural tannins in preparing the leather.

The interest of the experiment goes far beyond the possible help it may give in interpreting archaeological excavation. It will be a study in the genesis of some features of the landscape. Few parts of England, and certainly no part of the downs, have escaped man's influence on the soil; Fyfield Down itself is excessively rich in evidence of past tillage and disturbance. Yet few studies of soil movement have been made under the temperate conditions of southern England. The measurements of silting, compaction, percolating water, earthworm activity, and changes in the soil profile, that are all part of the experiment, should therefore offer new evidence of interest to physical geography and ultimately to the historical aspect of downland ecology.

P. A. JEWELL

Science in Ceylon

The fifteenth annual session of the Ceylon Association for the Advancement of Science was held in the buildings of the University of Ceylon in Colombo on November 26, 27 and 28, 1959. The Association has some seven hundred members and is divided into six Sections: (A) Medical and Veterinary Science, (B) Agriculture and Forestry, (C) Engineering, (D) Natural Sciences (Geology and Biology), (E) Physical Sciences, and (F) Social Sciences. Membership, unlike that of the British Association, is limited to those people with some qualification, and the Sections in some ways function like societies such as the Chemical or the Physiological Society in Britain. Sectional meetings may be held between annual sessions, and

some important lectures were given to Sections by visiting speakers during 1959.

The nature of the membership and the uniqueness of the Ceylon Association as a scientific meeting-ground in Ceylon mean that many specialised papers are given at the annual session, and that those giving general talks can speak in the knowledge that their audience is professionally interested in science. Thus sectional meetings have a flavour rather different from those of typical sectional meetings at the British Association, and are not usually organised as half-day symposia involving three or four papers on one subject. A valuable aspect of the size and organisation of the Ceylon Association is that members can attend all the addresses by sectional presidents and all the general lectures: no other Section meets during a given presidential address. The organisation of the scientific meetings and of the social programme by the Honorary General Secretaries, K. Arumugam and S. Wijesundera, could not have been bettered.

E. L. Foneseka, Professor of Chemistry at the University of Ceylon, was President of the Association, and his address on 'Landmarks in a century of synthetic dyestuffs and pigments' was a most stimulating survey of the history of this subject and recent progress in it. Most of the presidential addresses to Sections were reviews of recent progress in the subject of choice, and did not usually contain new information based on work done in Ceylon, except in highly applied fields. For example, L. H. Sumanadasa gave an interesting paper on 'Low cost housing in Ceylon' that contained new material based on his own work, though it did not contain an account of research in the ordinary sense of that word.

The chief guest of the Association, R. D. Haworth, Firth Professor of Chemistry at Sheffield, spoke three times to the Association, his most general talk being on 'Chemistry in every-day life'. A more specialised talk on 'Keys to current progress in natural product chemistry', was a masterly survey of a rapidly shifting field in which the main points of methodological advance were clearly brought out, and his specialised talk on 'Recent work on the chemistry of the tannins' contained unpublished material that obviously made a deep impression on Sections D and E. B. B. Lloyd, the British Association's delegate, gave a general lecture on 'Man as an experimental animal' and a more specialised lecture, mainly for Section A, on 'The regulation of respiration in man', and this included an account of unpublished work at Oxford done with D. J. C. Cunningham.

The non-presidential papers given to the Sections were mostly detailed reports of individual pieces of research, and of interest to a specialised audience only; they were usually given at times when three or four Sections were meeting simultaneously. Of about fifty such papers, only one or two were concerned with pure science, and the bulk were directly concerned with problems in Ceylon itself. The present writer naturally could hear only about a fifth of these papers, and found his sample to be sound and obviously important to the welfare of Ceylon; one or two of them, such as G. Obeyesekera's paper on '*Yakun Allanawa*—magical anxiety in Sinhalese women', were of considerable general interest.

The proceedings of the fifteenth session seemed to reflect very well the scope of scientific work in Ceylon today. This work is done mainly by the University and a few research institutes. It is clear that the very heavy burden of teaching and the sometimes oppressive climate combine to make research very difficult for the average university teacher, who is to be congratulated on what he does achieve. He needs more skilled technical assistance and research assistance from young graduates, and a much higher teacher-student ratio. There is any amount of material in medical, agricultural and natural-product fields for the research worker who wishes to do applied work, but the somewhat isolated though vigorous pockets of pure research in Ceylon need the strongest support, inside and outside the island, if the teaching and application of science are to continue to flourish.

B. B. LLOYD.

The Thornapple

Most parts of Britain had a dry warm summer with more or less drought conditions in many areas in 1959. The effects of the year's weather on the wild flora and also on many perennial cultivated plants will not be fully apparent for a year or more. Amongst unusual happenings has been the abundance of specimens of the thornapple received at Kew for determination and the many records published in the Press, both national and local. It appears that the weather conditions greatly favoured the

seed germination, seedling establishment, and later the flowering and fruiting of this plant. Attention was called to the poisonous nature of the species and sometimes undue alarm was caused by lurid headlines and exaggerated accounts of its being likely to cause illness and death. It is true that all parts of the plant are very poisonous to human beings if eaten. On the other hand, the plant is not one that would specially attract any one to experiment with its palatability. It has not, for example, the black shining juicy berries of the deadly nightshade, which make this native plant a special danger to children. There are, however, records of poisoning of children through eating the thornapple seeds which are said to have a somewhat sweetish taste. The seeds are enclosed in a characteristic four-valved prickly capsule. Farm livestock usually avoid the plant which has a distinct and (presumably to the animals) unpleasant odour and taste. Cattle, however, have been poisoned by eating the young leaves in hay.

As a poison the thornapple is classified as a deliriant as it causes illusions and delirium. The symptoms are similar to those produced by deadly nightshade but some authorities say the action is more rapid. There is paralysis, dilation of the pupils, suspension of secretion and of the inhibitory fibres of the vagus, leading to rapid action of the heart and poisoning may terminate fatally.

The thornapple (*Datura stramonium*) is, like the deadly nightshade (*Atropa belladonna*), a member of the potato family (*Solanaceae*). It is an annual and grows into a coarse, smooth, often rather bushy plant, two or more feet in height, with large, broad-wavy and toothed leaves. The flowers have fairly large-funnel shaped corollas averaging about 3 in. in length, opening often in June or July to somewhat later. The fruits are prickly, somewhat like those of horse chestnuts, and as they ripen they dry and split into four valves exposing the numerous rough blackish seeds which are somewhat kidney-shaped. The present range of the common thornapple is extensive. It has accompanied the migration of man from early times throughout most parts of the temperate regions of the world. It is variously known as thornapple (or thorn apple), stink weed, or Jimson weed. The last name is a corruption of Jamestown, Virginia. Its place of origin is not certainly known. Europe, Asia, and America have been suggested in various publications.

There are ten herbaceous species of *Datura* now recognised. All are apparently very similar in their biochemistry and all are poisonous. It has long been known that these plants have hypnotic, narcotic, and intoxicating effects when preparations of them are eaten, drunk, or smoked. In the Old World, Greeks, Chinese, Indians, and Arabs were familiar with the use, or misuse, of one or other species of *Datura*. In the New World, several species have been used in religious and ceremonial rituals by primitive peoples both in South and North America. In Russia thieves are recorded to have added extracts from seeds of *D. stramonium* to drinks they offered to their victims to make them dazed and stupefied.

All the species of *Datura* that have been chemically examined have been shown to contain alkaloids of the tropane class. Nothing is known as to the function of these alkaloids in the *Datura* plant. An alkaloid not belonging to the tropane class found in *Datura* is cuscohygrine. The most abundant alkaloid is hyoscyamine—the optically active form—with the racemic mixture known as atropine. Hyoscine, also known as scopolamine, is another fairly widespread alkaloid in the genus. Atropine, hyoscyamine, and hyoscine are sometimes referred to as the mydriatic alkaloids, since they cause dilation of the pupil of the eye (mydriasis). They, especially atropine, are often used in ophthalmology. Hyoscine is an excellent preventative of motion sickness (sea or air)—of course, in the proper dosage. Hyoscyamine sulphate is sometimes found in 'sea-sickness pills'. Hyoscine is used in obstetrics along with morphine as an analgesic producing 'twilight sleep'. Hyoscine has also achieved some notoriety as a truth drug.

W. B. TURRILL

Science Teaching in Secondary Modern Schools

A factual survey recently published by the Science Masters' Association reveals serious deficiencies in the provision of science teachers, laboratories and science equipment in many of the secondary modern schools in this country—deficiencies which are all the more crucial when one considers that nearly three-quarters of the nation's children attend such schools.

The facts given in the survey are based on replies received to more than 1,500 questionnaires

distributed to secondary modern schools in England and Wales. Many questionnaires were returned stating that no science was taught in the schools concerned: 73 because there were no science teaching facilities, and 33 because there were no teachers available who were capable of teaching science.

The Secondary Modern Schools Committee of the Science Masters' Association is of the opinion that there should be one laboratory for each 300 pupils in a school. This survey indicates that in 47 per cent of all secondary modern schools science is taught either wholly or partly under unsatisfactory conditions. 1,022 schools said, for example, that the laboratory was used as a form-room and 925 schools said that their equipment for the teaching of science was inadequate. The survey also reveals that only one science teacher in six in secondary modern schools is a graduate and that about one in six 'has no pretensions at all to science qualifications'.

In the opinion of Head Teachers three things are needed to improve the situation: (1) more science teachers; (2) more laboratory accommodation, and (3) more equipment.

Copies of the survey which is entitled *Science Teaching in Secondary Modern Schools* are available (1s. post free) from Mr. D. M. Chillingworth, The Village College, Swavesey, Cambridgeshire.

Granada Lectures

The second annual series of Granada Lectures, organised by the British Association and sponsored by Granada TV Network Limited, will be delivered in the Guildhall on the evenings of Tuesday, September 27, Wednesday, October 5 and Tuesday, October 11, 1960, at 8.0 p.m.

The lectures, which are delivered under the general title of 'Communication in the modern world', are intended to cover any relevant aspect whether scientific, social, political, psychological or otherwise, in its practical implications for modern man. The names of this year's lectures and the titles of their Addresses will be published in the September issue of *The Advancement of Science* as well as in the national press.

The lectures will be delivered before an invited audience: members of the Association who are interested in attending and who wish to apply for tickets should write during July for further information to the following address:—

Granada Lectures,
Granada TV Network Limited,
36 Golden Square,
Regent's Street, W.1.

It is planned to publish the full texts of the three lectures—which will also appear in book form at the end of October, 1960—in successive issues of the Association's Journal *The Advancement of Science*.

Forest Protection

The protection from injurious influences of Britain's 1,200,000 acres of state-owned forest is a continuous task, and everyone who has visited or passed through a Forestry Commission area will have observed the measures that are taken to deal with the main threat, that of fire. Other more insidious forms of damage, such as those produced by the attacks of fungal diseases and insect pests, have also to be guarded against. Prevention is always better than cure and in some cases this can be achieved by appropriate management or cultural means. Some insects, however, can attack perfectly healthy tree crops and damage from this type of pest, which is known as a primary one, cannot be avoided by good management. In such cases the early detection of an incipient outbreak so that control measures can be planned and the scale of damage reduced is of vital importance.

Currently the most important insect pest is the pine looper, *Bupalus pinarius* L., whose caterpillars defoliate pole-stage pines. Three outbreaks of this species have occurred within the last seven years and these have had to be controlled by the use of insecticides over some 6,500 acres, applied from aircraft or from fogging generators. To give early warning of the arrival of such outbreaks, all major pine forests are surveyed annually to determine the population density of the looper. This is done by counting pupal numbers during the winter months in sample soil quadrats and every year just under 100,000 acres of pine forest are inspected in this way. Quite apart from achieving its immediate

practical objective of detecting the occurrence of potentially damaging increases, the figures obtained from the survey may well, in the long term, be of interest to students of population dynamics, particularly since counts of the pine looper's parasites are also recorded.

DR. MYLES CROOKE

The lymexolonid *Hylecoetus dermestoides* L., whose larvae are wood-borers, has been regarded in Britain as a rare insect with very local distribution. In the past it has appeared at Sherwood, Cannock Chase, Stretford, near Manchester, and in the Highlands and the Tay Valley. Recently, reports and surveys have shown that it is becoming numerous in Argyll and central Wales.

Hylecoetus breeds in stumps and in felled or wind-blown stems of broad-leaved and coniferous trees. On the Continent it has appeared most frequently in oak and beech, and it also infests Spanish chestnut, birch, and gean. In Britain, now, Douglas fir, Sitka spruce, and larch are being attacked, particularly where thinnings have been left in the forest for some time.

The beetles emerge during May and June and the females lay their eggs singly or in groups in bark crevices. The larvae bore a minute hole in the bark and later enter the wood, following a winding radial or peripheral course in a horizontal plane. They penetrate quite deeply into the wood so that damage can be considerable. The life-cycle may be one, two, or even three years.

Hylecoetus could become a serious pest in the wetter parts of the country where its coniferous hosts are being felled and where, for various reasons, the timber cannot be quickly removed from the forest. More work requires to be done on the biology of this insect before its importance can be accurately assessed but, at the worst, control can be achieved simply by peeling logs exposed to infestation.

MISS J. M. DAVIES

Science in New States

In planning an international conference, to be held at Rehovoth in Israel from August 15 to 30, on science in the advancement of new states, the Weizmann Institute and its chairman, Mr. Abba Eban, have taken a line which is probably more in keeping with the aspirations of the younger Asian and African states than the douches of common sense that well-meaning observers from advanced countries are apt to apply. Practical applications are to be emphasised, but the scope of the conference is nothing less than 'to present a *general* picture of the achievements and prospects of the scientific and technological revolution of our times' including nuclear energy and electronics. The idea behind this is psychological. New nations, even small ones, Mr. Eban argues, wish to feel that they will be able within the foreseeable future to compete with the West on their own ground—that they are shut out from no form of activity. Preoccupation with the more glamorous, but also costly, branches of science has been noted by educationists with recent experience of various of the newer nations which will be represented at the conference. Detached advice given from outside would be to concentrate on agricultural and medical services to begin with, and train enough technicians to enable the more rudimentary applications of science in ordinary life to be made more widely than would be possible without them. But such questions as soil and water conservation, the role of chemical fertilisers in increasing agricultural production, and medical research in relation to endemic disease are included, in any case, in the conference programme. In place of the patronage implicit in the western or commonsense approach, there may be advantage in the end from confronting the leaders of new countries with the whole bewildering range of contemporary science, with many of its ablest leaders to explain it; and leaving them to conclude for themselves in what directions an effort made now can bring most advantage to their countries.

A. W. HASLETT

THE TERCENTENARY OF THE FOUNDATION OF THE ROYAL SOCIETY

By Sir HAROLD HARTLEY, F.R.S.

The Royal Society of London is the oldest scientific society in the world with a continuous record of activity and in July it will celebrate the Tercentenary of its Foundation. On November 28, 1660, twelve members of the group who had been meeting regularly at Gresham College after lectures by Christopher Wren decided to form a Society 'for the promoting of experimental philosophy'. From that time onwards we have careful records of their doings, but our knowledge of their earlier proceedings is fragmentary, derived from statements by Wallis and Sprat and from references to their meetings in contemporary correspondence. It is not surprising, therefore, that there are differences of opinion about the origins of the Society, inaccuracies have been copied again and again without being checked and far too much importance has been attributed to picturesque phrases like Boyle's 'Invisibles' without examining their probable significance.

To mark the occasion the Society is publishing two books: *A Brief History of the Royal Society*, by Professor Andrade, and a volume entitled *The Royal Society, Its Origins and Founders*, containing a fresh study of the origins by Professor McKie and twenty-one short biographies by different authors of the twelve Founder Fellows and of others who were closely associated with the early days of the Society. These biographies have never been brought together before and they throw a good deal of fresh light on the activities of the men who brought the Royal Society into existence. Professor McKie points out that the foundation of Gresham College in the City of London in 1597, with its resident professorships in astronomy, geometry and physic, provided a focus for those interested in the new philosophy and we know that a series of distinguished professors, Briggs, Gunter and Gellibrand, were working with the Deptford shipwrights and officials of the Royal Navy on problems of ship design and navigation in the early decades of the century. Sometime later, about the year 1645, there were meetings for scientific discussion of men like Wilkins, Wallis and Goddard and some of the London physicians which were held sometimes at Gresham College, where Foster was professor of astronomy. It may be that Henry Goddard, the wealthy Deptford shipwright, was a link between the earlier meetings

Fig. 1.—Sir Cyril Hinshelwood, O.M., President of the Royal Society.

Fig. 2.—Arms of the Royal Society as they appear in the Second Charter.

at Gresham College and those in which his son, Jonathan, took part later; but this we do not know, and there have been far too many inferential possibilities about these early days accepted as facts. Research is still needed in the State Papers and the letters of the period which may throw more light on these early meetings.

The Civil War had a decisive effect on their activities, as between 1648 and 1651 Wilkins, Wallis, Ward and Goddard were made heads of Colleges or professors in Oxford as a result of the parliamentary purge of Royalists. There they were joined by Petty, the professor of anatomy, and Willis, an Oxford physician, and by Wren, Rooke and Hooke, who were students, and in 1654 by Robert Boyle. The Oxford group became a strong centre of experimental studies, while the London group continued and was strengthened by the successive migrations from Oxford to professorships at Gresham College—Petty in 1650, Rooke in 1652, Goddard in 1655 and Wren in 1657. So there was much coming and going between the two groups, and Lord Brouncker, Sir Paul Neile and his brilliant son, William, as well as Ball and Hill were other new recruits in London. In 1660 the Restoration brought Wilkins and Ward back to London and it brought also an important accession of Royalists in Moray, Bruce and Evelyn, to whose influence with the king the Royal Society owes its Charter and its name. The twelve Founder Fellows, including Boyle, Brouncker, Evelyn, Goddard, Moray, Wallis, Wilkins and Wren, were a remarkable group of men, scientists and amateurs, and so the Society began its life under happy auspices. It was fitting that John Wilkins should have presided at the founding meeting and during the eighteen months that elapsed before the Royal Charter was granted either Moray or he occupied the chair. Lord Brouncker was nominated as the first President under the Charter. He was a Royalist, a mathematician of established reputation and a man of influence who served the Society well for fifteen years. Their early meetings were occupied with rather naïve experiments and with discussions that roved widely over fact and fable, until in 1662 Robert Hooke was made Curator of Experiments. His experimental skill, his fertility of mind and his inventiveness undoubtedly played a large part in the success of the meetings and the increase in the number of Fellows, many of whom, like Pepys, who became President in 1684, could claim no scientific knowledge.

In addition to their other activities the early Fellows exerted a threefold influence on the form and usage of the English language. They made English the accepted medium for scientific communications in place of Latin. There were notable exceptions, such as Newton's *Principia* (1687), but his letters on the theory of light and colour published in English in the *Philosophical Transactions* fifteen years earlier, were the prototypes of modern scientific papers. Then, as Pearsall Smith has pointed out, they gave a fresh meaning to older words with the new idea of progressive change in place of the classical conception of a static or declining world. *Improve* for example acquired the sense of 'making better' and one of its earliest uses with its modern meaning is found appropriately in the title of the 'Royal Society of London for improving Natural Knowledge'. Words like cohesion and tension first came into use at this time. Finally there was the appeal of John Wilkins in 1646 for a plain style in place of the elaborate prose of contemporary writers, which

quickly gained the support of his colleagues, and his influence was seen in the importance which the Fellows attached to simple language, an influence that was felt in much wider circles outside.

Just when the early enthusiasm for the Society was beginning to lose impetus and its finances were causing anxiety the genius of Newton gave it fresh prestige during the years of his active scientific life and his long Presidency of 1703 to 1727. It was a period when the Fellowship included many names of distinction, astronomers like Halley and Flamsteed, mathematicians like Cotes, McLaurin and De Moivre, and the father of plant physiology Stephen Hales.

Gresham College had been the birthplace of the Society with many earlier associations, and it remained its home until 1710, with a short interlude after the Great Fire when it was used to house the Royal Exchange and the city magnates and when the Society moved for a time to Arundel House. During Newton's presidency the Society decided to have a home of its own and bought a house in Crane Court in Fleet Street where it remained until 1780 when the Government offered it accommodation in Somerset House, whence it moved to Burlington House in 1857.

The middle years of the eighteenth century were a lean time for British science with few names of distinction apart from the President, Sir Hans Sloane, a physician whose great collections formed the nucleus of the British Museum. Then towards the end of the century came the long Presidency

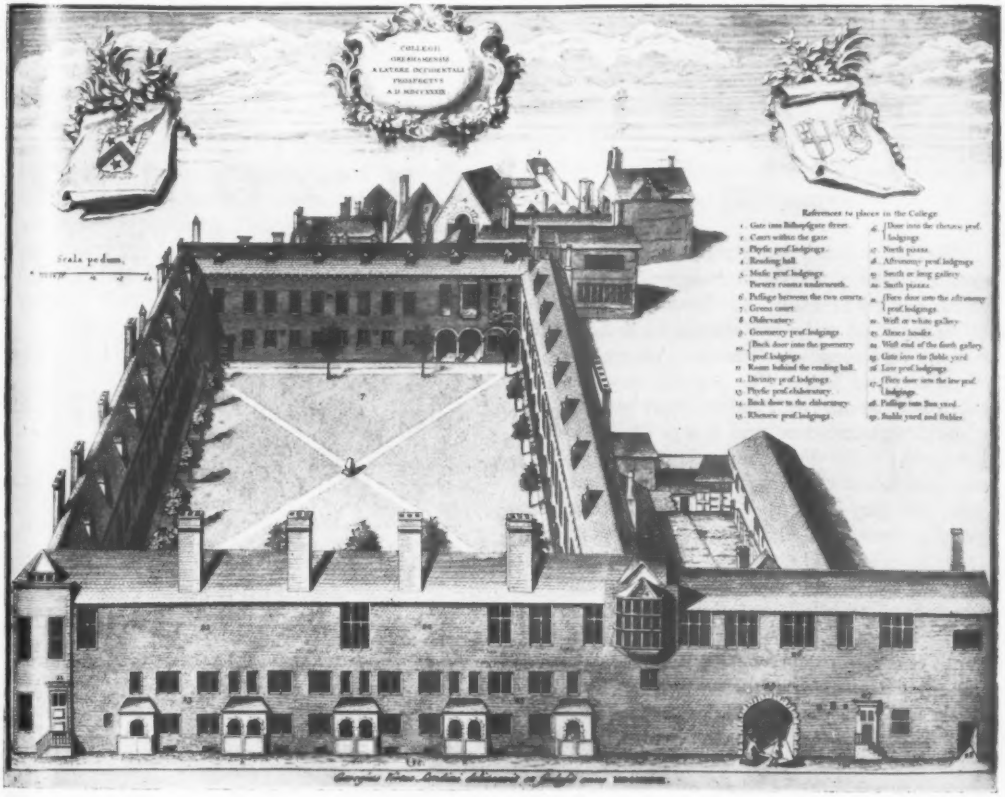

Fig. 3.—Gresham College.

Fig. 4.—Viscount Brouncker, First President of The Royal Society.

(1778–1820) of Sir Joseph Banks, botanist and explorer, who did so much to uphold the prestige of the Society at home and abroad. It was, too, a brilliant period of British science with the contributions of Cavendish, Priestley, Young, Dalton, Wollaston and Davy. The Society, however, still numbered among its Fellows many without any scientific qualifications and it was during Davy's Presidency (1820–7) and soon afterwards that there was much criticism of their presence and the influence they exerted. Gradually the scientists got the upper hand and the new Statutes of 1847 restricted the number of entries to fifteen a year and laid down the strictest procedure for elections which have been followed ever since. In previous years as many as forty or fifty Fellows had been admitted. Not infrequently the Presidents had had only social qualifications, but from 1850 onwards began the succession of Presidents each of whom has been an outstanding figure in British science. Some of the greatest episodes of scientific progress are associated with the names of Newton, Dalton, Faraday, Darwin, J. J. Thomson and Rutherford, and equally great advances in the applications of science to engineering are associated with the names of Watt, Kelvin and Parsons. Thus briefly has the Society over the span of three hundred years fulfilled some of the hopes of its Founders and Patron that its studies would be applied 'to further promoting by the authority of experiments the sciences of natural things and of useful arts ... to the advantage of the human race'.

In its first Charter the Royal Society was constituted a completely independent body governed by the President and Council and, unlike the French Academy, without any subsidy from the government. That independence the Society has always retained, but it has from time to time exerted its influence on public policy and its advice has frequently been asked for by governments. In its

PHILOSOPHICAL
TRANSACTIONS:
GIVING SOME
ACCOMPT
OF THE PRESENT
Undertakings, Studies, and Labours
OF THE
INGENIOUS
IN MANY
CONSIDERABLE PARTS
OF THE
WORLD.

Vol I.
For *Anno* 1665, and 1666.

In the *SAVOY*,
Printed by *T. N.* for *John Martyn* at the Bell, a little without *Temple-Bar*, and *James Allestry* in *Duck-Lane*,
Printers to the *Royal Society*.
Presented by the Author May. 30th. 1667

Fig. 5.—Title page from Volume I, 1665–1666, of the *Philosophical Transactions*.

early days the Society was much concerned with problems of navigation and the collection of scientific data by seamen and travellers. This tradition has continued through its influence with the government and the Admiralty in the despatch of scientific expeditions with which it has often helped. The list is a long one, beginning with Halley's expedition in the *Paramour* in 1698, the expedition to St. Helena to observe the transit of Venus in 1761, followed by Cook's voyage in the *Endeavour* accompanied by Banks in 1768, and in the *Resolution* in 1771. Then came the Arctic expeditions of 1773 and 1818. The *Challenger* expedition of 1871, which yielded such important results, was planned by the Society. In 1904 fresh ground was broken by Captain Scott's expedition to the Antarctic in the *Discovery*, arranged jointly by the Royal Society and the Royal Geographical Society. This was the prelude to the organisation by the Society of the I.G.Y. Antarctic Expedition with the Royal Society's base at Halley Bay from 1956 to 1960.

The Society has had intimate relations with the Royal Observatory from its foundation in 1675, and in 1710 Queen Anne appointed the Society to be its Visitors and Directors, an arrangement which continued until 1830, since when this responsibility has been shared with the Royal Astronomical Society. The administration of Parliamentary Grants-in-Aid for scientific investigations and publications, and the arrangements for British participation in the field of international relations in science are other responsibilities with which the Society is entrusted by the Government.

However, in the words of the President:

> Whatever the importance of its corporate activities, the most significant contribution it makes is simply the sum total of innumerable individual contributions made in very varied ways by the Fellows in their own right. They are of course free and independent agents, but the Society provides them with the means of publication, on occasion with financial help, and with an elaborate and sensitive mechanism for consultation and exchange of views on every kind of scientific matter. It constitutes in a way a kind of central nervous system of science in Britain.

The celebrations of the Tercentenary will occupy a fortnight starting on July 18. The opening ceremony at which The Queen will deliver an address followed by the President's address will be in the Albert Hall. The following days will be devoted to scientific lectures by a number of Fellows, to social gatherings and visits to Oxford and Cambridge and other centres of interest. Delegates are coming from the National academies of science and from universities all over the world.

ACKNOWLEDGMENTS

Fig. 1 is reproduced by courtesy of Mr. W. Bird and Figs. 2 to 5 by courtesy of The Royal Society.

BASIC IDEAS IN TOPOLOGY

By Dr. E. M. PATTERSON *Department of Mathematics, University of Aberdeen*

The word 'geometry' really means 'earth-measurement' and the type of geometry studied by the Greeks, known to mathematicians as Euclidean geometry, developed from practical problems relating to lengths and areas. However, mathematicians attach a wider meaning to the word 'geometry' and there are 'geometrical' theories in which the ideas of measurement play no part. In its early stages, topology was such a theory. It could be described as the study of the relative situations of geometrical figures, irrespective of their sizes and shapes; an alternative name was 'analysis situs'. In this introductory account, I shall restrict myself to a description of the basic ideas in geometrical terms, as this seems to me to give the clearest picture of the nature of topology. However, I should like to make it clear that some parts of modern topology are difficult to accept as being geometrical; the rigorous disciplines of modern Pure Mathematics have had a profound influence on the subject.

The following example illustrates topology as a study of the relative situations of geometrical figures. Consider the triangles in Fig. 1. We may

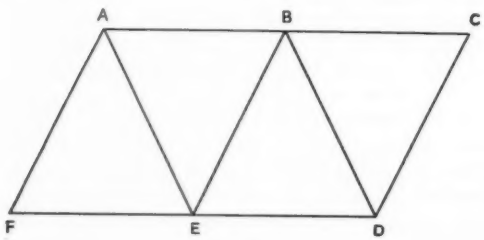

Fig. 1.

discuss the possible congruence of some of these triangles; if we do so, we are doing Euclidean geometry. But there are certain properties of the triangles that have nothing to do with their measurements, such as those involving collinearity and concurrency, which are the concern of projective geometry. An example of an elementary topological property is the following. Consider triangles *AEF*, *ABE* and *BCD*. Of these, *AEF* and *ABE* have the side *AE* in common; the triangle *ABE* is adjacent to *AFE*. Triangles *AEF* and *BCD*, however, have no points in common at all. Thus the situations of *ABE* and *BCD* relative to *AEF* are different, and this is not affected by a distortion of the figure to something like that shown in Fig. 2. We still have the property that

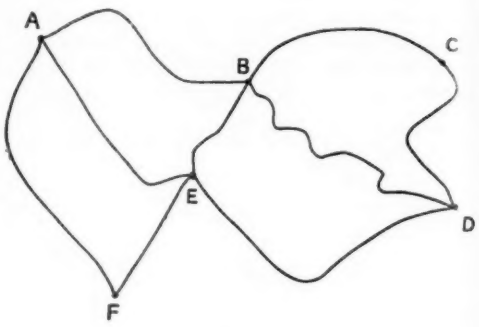

Fig. 2.

AEF, *ABE* have a side in common, and *AEF*, *BCD* have no points in common. The relative situations are just the same as they were before, although the sizes and shapes have been altered.

As a second illustration, let us consider an old problem dating back to the eighteenth century. This concerns the seven bridges of Königsberg. These linked together the banks of the two

branches of the river Pregel and the island of Kneiphof in the manner shown in Fig. 3. I have

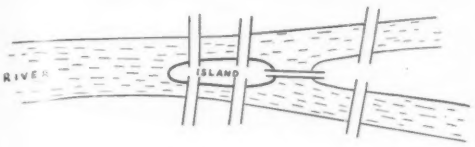

Fig. 3.

not attempted to draw this figure to scale. I have not considered the sizes and shapes involved, because the problem is not concerned with these. The question is this: is it possible to trace out a route connecting two points in the city and crossing each bridge once and only once? It is a topological problem, because the only relevant things are the relative positions of the bridges and the various portions of the city. The solution was first given by Euler, who showed that there is no such route.

In many branches of modern Pure Mathematics, we can bring the significant properties into focus if we consider in what sense we regard two different things as being equivalent. In Euclidean geometry, for example, the idea of congruence plays an important part. We regard two congruent triangles as essentially the same, because their corresponding measurements are all equal. The underlying physical idea is that two figures are congruent if each can be moved rigidly so as to fit exactly into the position occupied by the other. Mathematicians recognise this picture as useful but inadequate. It is inadequate because of the limitations imposed by physical space; for example, unless an object possesses the right kind of symmetry, it cannot be fitted by a rigid motion exactly into the position occupied by its mirror image. (Consider trying to fit your right hand exactly into a position previously occupied by your left hand.)

Congruence in Euclidean geometry is derived from the idea of preserving measurements. In topology we have a notion of equivalence derived from the idea of preserving relative positions. If two geometrical figures are such that each can be deformed continuously into the other without making breaks or joins, then the relative positions of the various parts of the figures will be the same. We therefore regard them as being equivalent for the purposes of topology, and describe them as 'topologically equivalent' or 'homeomorphic' figures. It is on this physical idea that the mathematical notion of topological equivalence is based. As in the case of congruence in Euclidean geometry, the physical idea is restricted by the limitations imposed by physical space; mathematicians have a more formal and more precise definition.

If we mould a piece of plasticine into different shapes, but do not join pieces together or break pieces off, then all the shapes we obtain are topologically equivalent. Thus, for example, the surface of a sphere is topologically equivalent to the surface of a cube, or to the surface of a cylinder with ends. An example of a surface not topologically equivalent to any of these can be obtained by rolling the piece of plasticine into a cylinder and then joining the two ends together. The surface so obtained is topologically equivalent to the surface of an anchor ring; mathematicians call it a torus. The hole through the middle of the surface precludes the possibility of deforming it into a sphere, so that these two surfaces are not topologically equivalent.

A sphere and a torus are examples of what are known as 'connected' surfaces. Roughly speaking, a connected surface is one which consists of one piece only. The property of being connected is topological; that is, anything topologically equivalent to a connected surface is itself connected. A sphere is a rather special type of connected surface; it is what is known as 'simply connected'. This means that any curve drawn on the surface so as to have no loose ends and no points where it crosses itself, a 'simple closed curve' in mathematical terminology, can be contracted continuously into a point without leaving the surface. Any surface topologically equivalent to a simply connected surface is itself simply connected. A torus is not simply connected, because a circle which 'rings' the surface as shown in Fig. 4 cannot be contracted continuously into a point.

The surface of a torus is topologically equivalent to the surface of a sphere to which a 'handle' has been added. We can add further handles to a sphere to obtain further topologically distinct connected surfaces. The general case is that of a

sphere with k handles, where k is a non-negative integer. The case $k=0$ gives a sphere, and $k=1$ gives a torus. A sphere with k handles is not topologically equivalent to a sphere with k' handles, unless $k=k'$.

As I have already indicated, topological equivalence is studied because it gives a means of emphasising the properties with which topology is concerned. If a feature persists when a change is made to any topologically equivalent situation, it is of some significance in topology. Any such feature is called a topological invariant. Suppose that we have two surfaces which we suspect to be topologically inequivalent. We may be able to prove this by calculating some particular topological invariant for each surface. If the values obtained are different, then the surfaces are not topologically equivalent.

The most celebrated topological invariant for surfaces is the integer known as the Euler characteristic. This is calculated for any surface by a process known as 'triangulation'. To triangulate a surface, we divide it up into regions, called faces, each topologically equivalent to the interior of a triangle in the Euclidean plane; a face is bounded by three curves, called edges, each topologically equivalent with a segment of a straight line in the Euclidean plane, the end-points of the line being omitted; and an edge is bounded by two points, called vertices. Every point of the surface is in a face, or on an edge or is a vertex. Every edge is adjacent to two faces, and has one vertex at each end. Let F, E, V denote the numbers of faces, edges and vertices respectively. Then the number $F-E+V$ can be shown to have the same value for a given surface no matter how it is triangulated. We call this number the Euler characteristic of the surface and denote it by χ. It is always an integer, but it may be negative. The most important thing about it is that it is a topological invariant. For a sphere, $\chi=2$ and for a torus, $\chi=0$. In general, for a sphere with k handles, $\chi=2-2k$.

Since χ is a topological invariant, and since its values for a sphere and a torus are different, we have another demonstration of the fact that these surfaces are not topologically equivalent. However it may happen for a given pair of inequivalent surfaces that the values of a certain topological invariant are the same. For example, if the invariant is the number of distinct pieces which form the surface, then the value for both a sphere and a torus is unity. Thus, in order to prove that two surfaces are topologically equivalent, it is not sufficient to calculate an invariant and obtain the same result for each. The invariant may be too 'weak' to distinguish between the surfaces. Since it is not usually possible to construct a topological equivalence directly, we may ask—how can we decide when two surfaces are topologically equivalent? This question leads naturally to the problem of classification of spaces in topology, and the remainder of this article is devoted to this question.

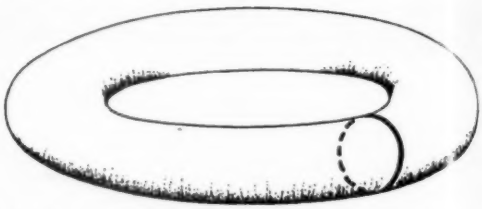

Fig. 4 is supposed to represent a ring-shaped surface (e.g. the surface of the inner tube of a motor-car tyre). The shading is for the purpose of making the figure look suitably curved. The heavy line towards the right is supposed to represent part of a circle ringing the surface; the rest of this circle is represented by a dotted line to indicate that it is not directly visible.

Let us consider a set of 'spaces' of some prescribed kind—for example surfaces in three dimensions like the spheres with handles which we have already considered. To classify such a set of spaces, we must obtain a standard set S, in which no two spaces are equivalent and which is such that every space in the whole set is equivalent to some space in S; also we must devise some method of deciding to which space in S any given space in the whole set is equivalent.

This classification problem can be answered completely in the case of surfaces of the kind we have been discussing. Such surfaces are usually described by mathematicians as 'compact orientable two-dimensional manifolds'. Roughly speaking, the word 'compact' in the present context means that the surface does not extend to infinity and is closed in the sense that no boundary points have been omitted. 'Orientable' can be taken to mean that the surface has both an inside and an outside. A 'two-dimensional manifold' is a space

for which each point lies in a portion of the space topologically equivalent to the interior of a circle in the Euclidean plane.

In the case of compact orientable two-dimensional manifolds it can be shown that a standard set S consists of spheres with k handles ($k=0, 1, 2, \ldots$). Thus any compact orientable two-dimensional manifold is topologically equivalent to a sphere with a certain number of handles. A method of deciding to which member of S a given compact orientable two-dimensional manifold is equivalent is to calculate the Euler characteristic χ. The manifold is then equivalent to a sphere with $\frac{1}{2}(2-\chi)$ handles. This shows that the Euler characteristic is a 'strong' topological invariant for surfaces of this kind, because no two inequivalent surfaces have the same value for the Euler characteristic.

The idea of a two-dimensional manifold can be generalised, in a mathematical way, to any number of dimensions. This raises the question of classification for compact orientable n-dimensional manifolds. For many years now, topologists have worked on theories whose ultimate goal was the solution to the classification problem for n greater than 2. However, not even for $n=3$ has the problem been solved, although many new theories have been invented and new methods have been discovered, some of them having applications to other branches of mathematics. In most of the work that has been done, algebra has played a vital part and much of the research now being carried out is not directly related to the classification problem but to problems in abstract algebra.

Recently, there has been an important new development. The Russian mathematician A. A. Markov has shown that the classification problem *cannot* be solved for manifolds of dimension 4 or more. Using a result proved recently in algebra on the impossibility of deciding whether certain equations solve in a certain way (that is all that I can say about it without becoming too technical), Markov has shown that no method can be constructed which enables us to decide, in all cases, whether two given four-dimensional manifolds are topologically equivalent. Thus a classification is impossible.

This does not mean that the time spent in seeking a classification has been wasted. Our knowledge of Mathematics would have been very much poorer had a solution to the classification problem been achieved thirty years ago.

MARINE AQUARIA IN THE LABORATORY

By **Dr. L. J. HALE** *University of Edinburgh*

A few years ago I visited that famous marine aquarium and laboratory in Naples in Italy, the object of my visit being to make some observations on the growth of hydroids. I took with me some aquaria. This may seem like taking coals to Newcastle, but they were rather special aquaria. They were in the form of a rather large and thick microscope slide made of 'perspex'; a shallow cavity was drilled out of the centre to accommodate my hydroid and two tubes were fitted so that a continuous stream of sea-water could be passed through it. It was made small so that I could observe the animal under the microscope. I had hoped that the hydroids would remain healthy for a day or two in it, but, in fact, even after a fortnight, they were as healthy as ever although they had had no food during this time. In contrast, material put in the laboratory tanks was looking pretty sick after a day, and was dead within two days.

The only feature of my tiny aquaria that could reasonably be considered as the cause of the healthy condition of my hydroid was the relatively rapid flow of sea-water through it. On my return to Edinburgh, I experimented with larger aquaria, also with a rapid circulation, and containing other kinds of organisms, and these were also a success (Hale, 1957). Maintaining a healthy marine aquarium I knew to be difficult, so it was possible that I had hit upon something which might enable marine animals to be kept in captivity with a greater success than had hitherto been possible. If this proved to be the case it would open up the great range of marine animals to all laboratories as material for study and research, a facility at present virtually restricted to marine biological laboratories. Biologists in University Departments might find such a tool particularly useful, as they are restricted in the times they can be away at marine stations. It might also provide useful information to marine ecologists. Biology teachers in schools would doubtless welcome such a piece of apparatus.

The scientific literature contains little information of a general nature on the effect of water movements on marine organisms, but the marine biologists do know a great deal about many other aspects of marine biology. Some of this knowledge (see Harvey, 1955) could be of particular interest in relation to marine aquaria, and I shall briefly discuss this.

One of the more important facts is that there is a circulation of nitrogen in the sea very similar to that on the land. All animals get rid of waste nitrogenous material. Most of those in the sea probably excrete it in the form of ammonia, some excrete similar compounds which are undoubtedly converted into ammonia.

It is also known that when animals and plants die their bodies are attacked by putrefying bacteria (unless they are eaten by other animals) and the nitrogen in them is converted to ammonia. Now ammonia is a poisonous substance and if it accumulated in aquaria, conditions for marine organisms would soon become impossible.

Fortunately, in the sea as in the soil, there are other bacteria which convert ammonia to nitrites and nitrites to nitrates. However, Oliver (1957) has indicated that nitrates are not above suspicion as being toxic, at least to some animals. It is here that the photosynthetic plants in the sea (algae, diatoms, etc.) come into the picture. They require the nitrates, and use ammonia and nitrites too, to build up their own plant bodies. The circulation of nitrogen is completed when we add that, directly or indirectly, all animals are dependent on plants for food to build up their bodies. Some, like winkles and limpets, eat plants directly, scraping small algae and diatoms off the rocks. Others, like the mussel, filter out particles from the sea-water, particles

which are minute plants and animals (plankton), and detritus. Others are purely carnivorous, for example the starfish subsists on bivalves such as mussels.

It is obvious that the bacteria are of the greatest importance. There are some interesting facts known about the conditions under which they carry out these reactions. They are all aerobic bacteria, requiring a plentiful supply of oxygen dissolved in the sea-water. It is possible that they are found mainly on solid surfaces, and only a small minority float freely in the water. There is some evidence that they convert ammonia to nitrites and nitrates more quickly when their substratum is chalky, such as mollusc shells. There is some evidence that microscopic particles suspended in the sea-water form a suitable substratum for them. A curious thing about these bacteria is that they must have iron to be able to convert the ammonia to non-toxic substances. Fortunately, diatoms contain iron. Iron is also found in suspended particles, and it is possible that these particles tend to collect up some of the ammonia. So the suspended microscopic particles take on a particular importance; each may well be a minute factory, possessing all the machinery necessary to remove toxic ammonia from the water.

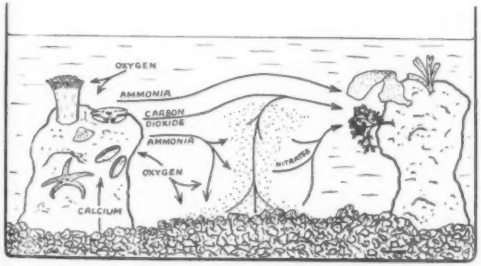

Fig. 1.—Diagram to illustrate an important function of a circulation of water in a marine aquarium. The moving water transports materials from one kind of organism to another and keeps microscopic particles in suspension.

Beneath drawing: Animals
Bacteria (solid surfaces and suspended particles)
Photosynthetic plants

On arrows: Oxygen
Ammonia
Carbon dioxide
Ammonia
Oxygen
Calcium
Nitrates

Putrefaction of dead organisms is carried out by bacteria. With a plentiful supply of oxygen the material is converted to ammonia and carbon dioxide. But if the amount of oxygen is low different kinds of bacteria thrive and produce those evil smelling and toxic substances so characteristic of an aquarium which has 'gone wrong'.

Of importance too are the photosynthetic plants to remove the inorganic nitrogenous substances. These plants need light; some of the diatoms flourish in subdued light, but the bigger algae undoubtedly need a much stronger source. These plants also have the advantage that they require carbon dioxide which is the waste respiratory product of animals and bacteria. Accumulation of carbon dioxide makes the water neutral or even slightly acid, whereas in the sea it is slightly alkaline. So the plants have another advantage in preventing this unfavourable tendency to acidity.

A word is necessary about those organisms, such as molluscs and crustacea, which build skeletons of calcareous material. These animals need quite a lot of calcium for this (Wilbur and Jodrey, 1952), and they extract it from the sea-water. The calcium in the sea-water in an aquarium would soon be depleted by a number of such animals unless it were replaced. This is another advantage of including chalky materials such as mollusc shells.

Let us apply this knowledge to a marine aquarium. It must be inoculated with ammonia-attacking bacteria and putrifying bacteria. This is easily done by introducing broken mollusc shell, sand, stones and rocks collected from the shore; these also supply solid surfaces on which the bacteria live, and the mollusc shell will form a calcium reserve should we wish to keep animals with calcareous skeletons. Then we must have photosynthetic plants to absorb the ammonia, nitrites and nitrates. With only subdued light many diatoms and other small green algae will flourish and carry out this job for us. We must also encourage suspended particles, partly to help in dealing with the ammonia and partly because they are necessary for those animals which filter them out for food.

Most plants, many animals, and much of the bacterial population are sedentary, and therefore the materials they require for their livelihood must be brought to them, and their waste products flushed away, else their immediate surroundings will become poisoned. And notice also that the

waste product of one sort of organism is the food of another sort. Clearly there is one straightforward way in which all the inmates of an aquarium can be satisfied, and that is by an energetic circulation of aerated water. Such a circulation will also keep those beneficial particles in suspension (Fig. 1).

But this is theorising; the important thing is, does it work in practice? Well over two years ago I designed an aquarium which had eleven tanks connected together in series. A pump propelled the water from tank to tank, the same water being circulated the whole time. The water was not filtered. The bottoms of most of the tanks were covered with a layer of broken mollusc shells; one or two had sand to accommodate sand-dwelling creatures, and some had stones and rocks in them. A wide selection of animals was collected off the shore and put in the tanks.

The great majority of the animals have lived for long periods. To quote one or two examples, some small sea-urchins (*Psammechinus*) and starfish have lived for well over a year, plumose anemones (*Metridium*) grow and reproduce continuously, two tube-worms (*Sabella*) have been with us from the beginning, a full grown lobster is still as lively as he was two years ago, has moulted twice and regrown a lost chela. Among others I could mention are many different kinds of sea-anemones and crabs, the Norwegian lobster, sand worms, scallops, an octopus, and different kinds of fish. The smaller algae, and especially diatoms grow well, but I have not been so successful with the larger algae. This is almost certainly due to there being insufficient light, and I am now installing some fluorescent tubes to remedy this.

Pumping sea-water has its problems, and the method I have developed is that of using the well-known 'bubbling tube'. The water is piped to the bottom of a vertical tube (the bubbling tube), and into the bottom of this tube air is injected. The bubbles which form rise to the top carrying the water with them. Such a pump is surprisingly efficient to run. A 5 ft. length of $\frac{1}{2}$ in. bore tube will pump about 25 gal. of water an hour for the expenditure of about a cubic foot of air (Fig. 2). The pump on my aquarium has twelve such tubes, and its normal capacity of 300 gal. of water per hour can be raised to 500 gal. by increasing the rate of air injection. Such pumps can be very simply made in 'perspex', with polythene or P.V.C. tubes. There

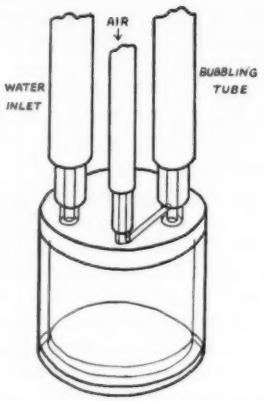

Fig. 2.—A simple water pump for marine aquaria. With $\frac{1}{2}$-in. bore tubes its capacity is 25–40 gal. per hour.

Water inlet
Air
Bubbling tube

is no metal to corrode, or to contaminate the water with toxic metallic substances, and no moving parts to be damaged by sand particles. An occasional clean is all the maintenance it requires. Notice, too, that this kind of pump also aerates the water; no further aeration is necessary.

Circulation of the water is no new feature of aquaria, but as far as I am aware, it is not carried out on the scale which I have found necessary for a healthy aquarium. A sluggish flow is better than stagnation, but the success I have had, so far, in keeping so many different animals has been by providing a really active flow. After all, this only attempts to reproduce the really active water movements in the sea due to tides, currents, and waves. In the sea, flow of water must be commonly of the order of a knot, and often a good deal faster. In my aquarium the maximum water speed is still considerably less than this—about 0·4 knots.

The line of thought which led to the development of this aquarium was triggered off by noticing that hydroids grew well in the current of water in my tiny Neapolitan aquaria. But the water I used for this was fresh sea-water, and the functions I have ascribed to the sea-water in my closed system aquarium were certainly not operating here. Sloane and his colleagues (1957, and earlier papers) and McDougall (1943) have shown that some sedentary

animals prefer living in a current, but the reasons they suggest for this preference do not apply to my hydroid in its small aquarium. One would expect that a sluggish flow would be quite adequate to supply such a small animal with all the oxygen it needed and to carry away the ammonia it produced. So it looks as if the current of water has some further function, and if this is so I have to admit that I do not know what it is. Perhaps readers of this paper may have some suggestions to make.

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THE COMMUNICATION OF SCIENTIFIC CONCEPTS AND MODELS OF SEMANTIC MECHANISMS

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There are relatively few well-attested facts (in a scientific sense) concerning the work of scientific writers but since the last war there has been a rapidly growing awareness of their problems. Courses, meetings, and publications all testify to an urgent sense of need.[1] Manuals for writers are now numerous. These are empirical recipes rather than scientific formulae but they embody a good deal of what may be called craft-experience and this is a necessary starting-point for a scientific technology of writing. But we need to know a good deal more about the writers themselves. We also need to know more about readers.

Research on reading fills volumes of educational and psychological literature. The bulk is concerned with the young reader and the backward reader.[2] The growth of Reading Clinics testifies to a widespread need at the adult level for improvements in reading habits. Even a superficial enquiry reveals that the industrial, the technological and the scientific readers have more or less serious problems of comprehension.[3]

The problems of writer and reader alike are bound up with the wider problems of language and it is the immensity of this field which is apt to scare the research-worker on communication into a condition of agoraphobia. He is inclined to retreat into the seclusion of narrow and highly specific experiments of commendable rigour but of dubious general significance and no conceivable practical application. Certainly to get anywhere at all we must narrow our enquiry down to sharply defined questions but these need not be trivial, nor need they lack an objective.

The assumption underlying the present enquiry is that since words are the raw material of the writer his greatest technical need is to gain insight into this strange and powerful material. True, he can be given practical techniques of writing but unless these are based on insight into language they are no more than conventions, traditions and rule-of-thumb recipes. If only he could understand how language works he could devise his own techniques.

Now we know how radio communication works. It works by resonance. The transmitter sends out certain frequencies of vibration and the receiver vibrates in unison. Is there any sense other than that of vague analogy, in which we can speak of 'resonance' in the reader in response to the words of the writer? Is there a process of *semantic resonance*? I think there is and this is the question with which I shall concern myself here.

There is a striking historical contrast between radio and verbal communication. Man has used verbal communication for thousands of years but still does not understand how it works. Radio was understood before it was ever put to work. The work of Faraday and Clerk-Maxwell on the electromagnetic field laid the theoretical foundations of radio before Hertz and Marconi could strike their first sparks. Unlike most technologies, which start by rule-of-thumb and gradually become more scientific, radio was a direct application of pure science from the start. Its immense flexibility and power today scarcely need emphasis. But in our use of words we show little more skill than the ancient Hebrews and considerably less charm, most of us.

Now language is such a complex phenomenon that any simple explanation of its working would at once be suspect. But granted that the full explanation must needs be pretty elaborate could it not, nevertheless rest on a fairly simple basic mechanism? Let us explore the possibility of a simple theoretical model of the elements of language.

There are just four ways in which a theoretical model can be expressed, namely:

(*a*) in words,
(*b*) in mathematical symbols,
(*c*) in diagrams,
(*d*) in mechanical hardware.

Each of these forms has its advantages and each has its limitations, on which I need not elaborate. But a theory of *language* which is expressed entirely in words obviously runs a serious danger of question-begging. A mathematical theory will be incomprehensible unless the symbols are translated. If translated into words we are back where we were. Diagrams present the same dilemma. Only a mechanical model can actually perform and *exhibit the consequences* of its own construction without verbal ambiguity. Let us then experiment with a crude mechanical model of language.

Every writer, whether explicitly or intuitively works on the assumption that his words will produce a response in his readers. And not just any response but a more or less definable response in accordance with the author's intentions. Let us express this slightly differently. A certain pattern of excitation in the brain of the writer (viz. his intentions) causes the emission of a certain sequence of radiations (viz. his words) which fall on the absorptive surface of a kind of 'black body' (viz. the reader's brain) and arouse there another pattern of excitation (viz. the response) which is partially isomorphic with the writer's pattern of excitation.

Now isomorphic simply means 'having the same form' and is a mathematical abstraction. It merely restates the problem, it does not solve it, viz. the problem of ascertaining just what happens when a reader understands a writer. The concept of *semantic resonance* which I shall now put forward is intended to clothe the bare bones of 'isomorphism' with the flesh and blood of a working hypothesis. In the space available I can do no more than offer a crude sketch of this hypothesis, leaving the subtleties, refinements and qualifications for a fuller exposition. This account will therefore be rather more concrete than the theory strictly warrants, even to the extent of being embodied in a mechanical model. For interest and attention are more likely to wander away from precise abstractions than from rough concretions. And gross errors are more easy to correct when grossly expressed.

The strange goings-on in the Crooke's tube excited the attention of J. J. Thomson in the 90's. The word 'electron' was first applied in 1894 by G. Johnstone Storey to the hypothetical corpuscle of negative charge. Exactly sixty years ago Thomson presented his experimental evidence for the existence of these corpuscles. As Whittaker tells us[4]: 'Even in 1899 most physicists did not fully believe in Thomson's ideas. At the British Association meeting at Dover in September of that year, he read a paper *On the existence of masses smaller than the atoms* to a deeply interested but not altogether convinced audience.'

In this paper[5] Thomson demonstrated the existence of a 'fourth state of matter'. I should have too much presumption on my conscience if I claimed to be able to demonstrate the existence of a 'fifth state of matter'. The analogy here drawn with the electron should be taken for what it is—a deliberately crude expository device for giving quasi-pictorial expression to a concept too complex to be briefly presented otherwise. The 'fifth state of matter' here proposed consists of *clusters of excitation in the brain*. If I call each such cluster a 'semantic particle' I am being both provocative and expository: provocative in suggesting that the *mind*, in which alone 'meanings' can be said to be meaningful, may profitably be conceived as *corpuscular*; and expository in declaring that when we investigate the language-storage mechanism of the brain we are driven to postulate the existence of very large numbers of entities which not only exert semantic functions but which are discrete, active and mobile. These particles may not be material in the sense in which a grain of sand is commonly regarded as material—but nor is an electron 'material' in that sense either. Physical particles are not conceived as material in any gross sense—indeed it is precisely because they are called in to explain the gross properties of matter that they themselves are divested of all grossness, otherwise the explanation would be circular.

Similarly, it is precisely because meaning is mental that we have to seek non-mental terms in which to explain it. It is the complete failure of the vitalists to grasp this principle that provoked the mechanists and behaviourists to a more extreme statement of their position than the case warranted. Biologists and psychologists should recognise that they are in precisely the same position as the physicists. If you want a genuine non-circular explanation of anything you must introduce terms different in kind from the terms of the fact to be explained.

Thus if we are to explain such phenomena as 'meaning' and 'understanding' we have to introduce non-mental terms. And we have the support

of no less an authority than Sir Charles Sherrington for adopting *motion* as the explanatory concept. In spite of his preference for dualism Sherrington declared[6]—'Mind, recognisable mind, seems to have arisen in connection with the motor act.'

Now it will begin to seem like a repetition of an old story. The mystery of heat was supposed to be explained by the hypothesis of the fluid caloric, essentially a circular explanation. Caloric had to give way to the kinetic theory which asserted that heat must be explained by something which, on the face of it, was not hot, viz. the motion of molecules. And now comes my proposition that *understanding*, essentially a mental process, is to be explained in terms of the motion of particles. What is the nature of these particles? Before dealing with this question I must point out that the kinetic theory of heat did *not* explain heat in the fullest sense of the word. For heat has two aspects. It produces certain physical consequences such as expansion and combustion. But it also produces psychological consequences, viz. thermal *sensations*. The kinetic theory does not explain the latter. It can account for the stimulus but not for the response. Now the simplest definition of 'understanding' is 'an awareness of important relations'. The theory of semantic particles seeks to explain the *relations*, not the *awareness*. It is *not*, repeat *not*, a final and comprehensive theory of 'mind'.

When the mind is in its receptive phase we can distinguish three distinct levels of awareness, viz. an emotional level, a perceptual level and a cognitive level. To evoke these responses the writer readily falls into one or other of three different modes of writing: the *emotive*, the *descriptive* and the *expository*. Although these three overlap a little the distinctions go very deep. Although the greatest art is emotive it does not always need art to arouse emotions. It does not even need language, essentially. Indeed direct behaviour, aggressive, erotic and so on will arouse emotion more surely than words. Further, the number of distinct *types* of emotional response is very limited, perhaps a few dozen in all. Perception, on the other hand, is much more variegated. If we consider perception in terms of the sensory qualities involved (rather than in terms of objects perceived, which takes us over into cognition) we have various estimates of the number of distinct qualities experienced in each of the different modalities—vision, hearing, taste, etc., and these run into thousands. Thus we need to seek brain mechanisms which can preserve large numbers of discriminations. When we come to cognition proper, and consider the intellectual discriminations involved and preserved in our use of language, of mathematics, of inventions, of economic, social and political responses, of scientific thinking, if we could count them they would run into many millions. Thus there is a numerical basis for our distinction between emotions, perceptions and cognitions, the different orders of magnitude of tens, thousands and millions. It is not unreasonable to suppose that the brain provides somewhat different mechanisms for storing and exciting these basically different discriminations. It is therefore not surprising to find theories such as the psychoanalytic and Gestalt theories, which throw a good deal of light on emotional and perceptual phenomena respectively, breaking down over problems of language and comprehension—just as the earlier rationalistic explanations of emotion were quite inadequate.

There is no need to point out that language and intellect are inextricably mixed up. Yet it would be wrong to identify the two. There are many aspects of language which are not rational and there are many intellectual processes which use non-verbal elements. But before we can go further in this analysis we must consider what exactly is a *word*. And here I find myself driven to call in question one of the most firmly entrenched premisses of modern philosophy, namely the distinction between *words* and *things*. The rejection of this distinction is one of the cornerstones of the theory of semantic particles and therefore cannot be burked.

What do we mean by a 'word'? We can use it in a quite abstract sense to refer to a class of occurrences all having reference to something briefly called a 'meaning', or an object, event or what you will. This does not take us very far for it leaves open the question whether we are using 'word' to refer to something on paper, in the air, on the retina, in the cochlea, in the brain or in our experience, or in the motion of a pen, or in the vibrations of our vocal organs, or on magnetic tape or in a dozen other places. 'Word' is a thoroughly ambiguous word. To say categorically that 'words are not things' is to say, *inter alia*, that an ink mark on paper is not a thing. It must also mean that when a cerebral haemorrhage knocks part of the brain out of action, producing aphasia, that part of the brain is not a

thing. Contrariwise, if things are fundamentally distinct from words then a red light, a flag, a cross and many other concrete symbols have nothing in common with words. As Wittgenstein said[7]: 'This general notion of the meaning of a word surrounds the working of language with a haze which makes clear vision impossible.' Unfortunately for us Wittgenstein left his own vision in such a form that only full-time Wittgensteinian philosophers can understand it. So our confusion remains.

This confusion would not have arisen if philosophers had been more philosophical and recognised that 'word', 'symbol', 'sign' and all terms of that type are expressive not of a kind of entity but of a *relation*. We use the term 'mother' to refer to a person but that person is also herself a daughter. These relation-words always entail a second term, whether stated or not. And 'word' itself, say, the word 'cat' entails, e.g. a certain mark on paper having a certain relation to a certain species of animal. Countless confusions could be avoided if the thoroughgoing relativity of *all* linguistic terminology were explicitly recognised. The same applies to grammatical terms. No word *in itself* is a noun, a verb, etc., but only through its function in a sentence. When Shakespeare said, 'But me no buts,' he made a word normally used as a conjunction to serve first as a verb then as a noun.

Is it surprising that words should turn out to be thus so thoroughly infected with relativity? For words have evolved for purposes of communication, and communication is the very stuff of relationship. Every word may thus be regarded as a molecule of relationship. Language as a whole makes up the substance of communication. To understand this relation we have to consider the two terms related, viz. speaker and hearer, or writer and reader. The medium between the two is sound or light. These are physical energies. They carry no experience, no meaning, no mind. Whatever experience these physical radiations evoke in the listener must come from his own resources. And therefore, insofar as we can speak of the listener or reader *understanding*, it can only be by virtue of some *resonance* which these radiations of language set up in his brain, a pattern of brain-action in some degree in tune with that of the communicator. But this pattern can have little in common with the manifest physical form of the words spoken or written. For often the same thought can be conveyed by many alternative forms of expression. This indeed is one of the basic problems which any psychological theory of language must face.

Since 'word' has such a multiple connotation it is useless to ask how words are stored in the brain and how they behave in action. The evidence from cases of *aphasia* shows clearly that a word is not a neurological unity. May I recall what Sir Russell Brain said in the symposium on Semantics at the Bristol Meeting of the British Association?[8]

> . . . as we learn to speak we learn to attend physiologically to the pattern of sounds which are characteristic of a particular word however it may be uttered and in order that we may do this there must exist in the nervous system a physiological disposition for each word which I have called an auditory word-schema. This schema is, as it were, a resonator which reacts to the pattern structure of an individual word, and it is thus an essential link between a word and its meaning, for the varying physical stimuli and the varying peripheral reactions to them which represent a word can evoke that word's meaning only by evoking a reaction in the corresponding auditory word-schema. But this is only the beginning of the story. A word may have many meanings, and in a given instance its particular meaning may be determined by the other words with which it is associated in a sentence. In this, temporal sequence and relational words are all-important. Hence, in speech the nervous system has to deal with sentence-schemas as well as word-schemas. But the word-schema is a more or less fixed, atomic element in the brain. The sentence-schema in spoken speech is, as it were, molecular, being built up in the actual process of speech out of word-schemas, and demolished as soon as it has served its purpose which is to evoke its meaning. Thus the word is the unit of language and the sentence is the unit of speech.
>
> But of course both a word and a sentence often possess meaning only in relation to their context, which may be non-verbal and may include gestures. 'Give me that', for example.
>
> In the case of a literate person there is a further complication. When we learn to read and write we learn to associate in a complicated fashion visual symbols with the sounds of words. This involves the creation of visual word-schemas and enriches the auditory word-schema which previously reacted only to the sound of words spoken but now comes through the visual word-schema to react also to the signs of words written or printed and may now be termed the central word-schema. Let me emphasise that a word-schema is a physiological disposition. When we hear someone speak we are conscious of the sounds of the words he utters, a particular group of auditory *sensa*, we are not conscious of the corresponding word-schemas. The

physiological word-schema thus corresponds to the abstract notion of a word as a linguistic unit.

Now the concept of the schema has nearly fifty years of history behind it and is coming to play an increasingly central role in psychological theory[9,10,11]. It would not be possible to give a logically consistent exposition of all the uses of the term but scientific concepts during their growth have often displayed a healthy disregard for logical rigour. If successful they create their own logic. 'Schema' has so many 'mental' attributes attached to it that the simplest description of it would be 'a fragment of mentality'. The 'semantic particles' which I now wish to discuss represent an attempt to give physical reality to this concept.

I shall not attempt any hypothetical description of the neural structure of these particles. The approach will be *via* mechanical models. The astonishing performances of the large electronic computers should not lure us into the supposition that we are yet within sight of an adequate model of the human brain. It may be that when such a model is forthcoming it will take the form not of one great giant computer but rather of a hierarchy of different types of smaller computers. And when we come to the representation of semantic particles which, as already indicated, must exist in millions, we may have to envisage a pool of micro-computers to perform their functions.

It is a pity that the word 'computer' has now become fixed by usage for machines which do a great many things besides computing. They are more adequately described as 'information handling mechanisms'. The semantic particle may be defined as an *active packet of information*. Its activity must include mobility and a capacity to activate other particles. In the mechanical model these properties are represented by actual *motion* in space and by *radiation*. Each particle is constructed so as to be sensitive to part of the spectrum of other particles, whilst having its own distinctive spectrum of emission. But the physical properties of the model are to be regarded only as analogues of the properties of the quasi-particles in the brain itself. It is not necessary to picture fragments of words actually floating through the brain-substance and radiating messages to each other. But the model suggests that the neurophysiologists might start looking for neural processes which *simulate* motion and radiation.

Thus the model uses motion and radiation to express certain important semantic processes. In terms of these processes we begin to build up a coherent account of the way in which the brain uses language. Psychological experiments using verbal stimuli are almost as old as experimental psychology itself and we have an enormous mass of empirical findings with which to illustrate and check the theory[12].

The theory asserts that in early infancy the flow of experience begins to be broken up by discriminative operations. Each such operation ties up a little packet of unique information into an independent and enduring neural mechanism. The operation, in general, involves a learning-process and is spread over a period of time. These mechanisms are the semantic particles. The generative process is slow at first but proceeds at an accelerated pace in early childhood. The particles embody the whole range of discriminated sensory experiences.

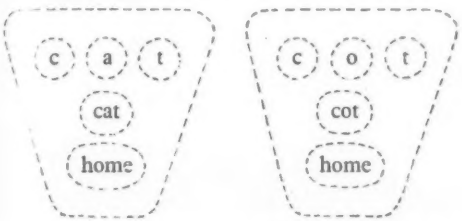
A second process starts up probably not long after the first, a process of *clustering*. Particles having certain information in common exert a mutual attraction, and form clusters. The model is so constructed that one machine receiving radiation from another machine starts moving towards it. (These machines will immediately suggest comparison with Grey Walter's tortoises.[13] These have a scanning device which controls the driving mechanism so as to move the machine in the direction of the incident light. But whereas Walter's machines were conceived as model organisms the semantic particles are conceived as models of discrete packets of information *within* the organism. They differ from computers in that the latter has a memory store on a drum or other device separate from the operational mechanism, whereas the semantic particle is both a store and an operator.)

It is through the clustering of particles that the formation of words and concepts is represented. A purely practical difficulty in the making of the models arises here. An example will illustrate. The particles represent the *schemas* of all elements of experience including the sounds of words and the appearance of objects. The child learns two similar words, say 'cat' and 'cot'. Each has three phonemes, viz. c, a, t and c, o, t. With each is associated the schema of an object, a piece of furniture and an animal respectively. These two are distinct but have at least one piece of information in common,

viz. that both occur in the child's home. Thus a very simple analysis gives us seven distinct packets of information, viz.:

(1) sound of c
(2) „ „ t
(3) „ „ a
(4) „ „ o
(5) appearance of cot (furniture)
(6) „ „ cat (animal)
(7) home

The clusters of particles representing the two words can be shown thus:



Now are we to suppose that each cluster is a permanent association of particles? If so then the particles for (c), for (t) and for (home) must be duplicated. And they must be copied over and over again for every new cluster. The alternative is to suppose that each cluster comes into existence only at the moment of use and is then instantly dispersed leaving its particles free to enter new combinations. Which method the brain adopts I do not know but the second alternative presents serious theoretical difficulties. The first presents practical difficulties for the model-maker since it requires the installation of a reproductive mechanism enabling particles be to replicated as required.

The function of these models is to provide a concrete language in which to discuss linguistic problems and to suggest hypotheses for experimental exploration. Conceptual and linguistic forms are all treated alike as packets of information. The information is uniformly represented in the model by means of spectra. Each spectral line, and hence each set of spectral lines, is unique. Each model particle has its own spectrum together with a driving mechanism which causes it to seek out other particles having certain spectral lines in common. Thus these machines are called 'Chromatropes', meaning 'colour-seeking devices'. In the first demonstration model actual colour is used in order to make the display as visible as possible. But for obvious technical reasons it will be necessary in later more elaborate models to adopt radio frequencies in place of the visual spectrum. Alternatively we could, of course, adopt sound-frequencies and call the particles 'Phonotropes'. This would have a certain suggestive value. The particles could be imagined as calling to one another. When we hear a word we do in fact speak of its 'calling up' associations. We can picture the brain as containing a large population of words and concepts calling out over-lapping messages when stimulated and forming shoals held together by various semantic relations.

With such a theory we must begin with the simplest possible examples. The first demonstration is the 'One-dimensional Canal Model, Chromatrope Mark I' containing simply two machines able to radiate to each other and to attract or repel or be indifferent to each other (Fig. 1). The second demonstration, which will be very expensive to produce is the 'Two-dimensional Tank Model, Chromatrope Mark II' containing enough machines, at least a dozen, to swim about and form clusters. The third demonstration must be purely notional. It is the 'Three-dimensional Oceanic Model, Chromatrope Mark III'. Only on such a scale will it be possible to approximate to the complexity of linguistic processes in the brain. But with Mark II we can begin to lay the foundation of Chromatrope Mechanics, Statistics and Logic. For what Elsasser[14] says of behaviour patterns in general is especially applicable to the mathematics of the Chromatrope, viz. 'As a general rule they are describable only in terms of multiple (and therefore essentially statistical) relationships to other preceding patterns'.

We should then develop these theoretically to calculate what *should* happen in the Oceanic Model. Parallel with this we should hope for a simulation of Chromatrope mechanics by means of electronic parameters in a computer.

In his posthumously published Silliman Memorial Lectures[15] John von Neumann laid bare some fundamental objections to any close analogy between the brain and the digital computer. He also pointed out the contingent and historical character not only of natural languages but of mathematics itself. 'Just as languages like Greek or Sanskrit are historical facts and not absolute logical necessities, it is only reasonable to assume that

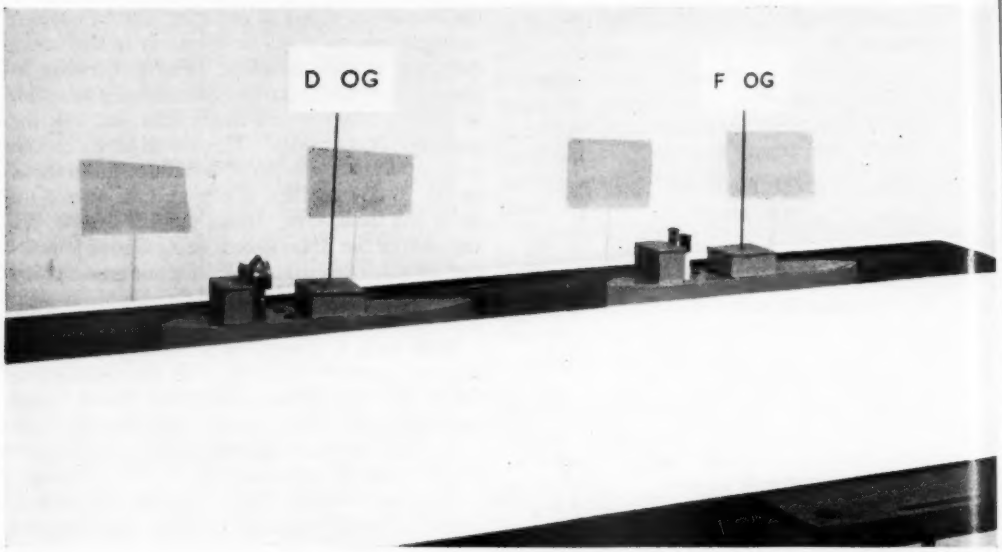


Fig. 1.

logics and mathematics are similarly historical, accidental forms of expression.' And further: 'When we talk mathematics we may be discussing a *secondary* language, built on the *primary* language truly used by the central nervous system.'

What von Neumann, and many others including Egon Brunswik, have indicated is the reasonableness of expecting an adequate theory of brain-functioning to have statistical characteristics. Thus we should expect it to display *plurality*, *variability*, *redundancy*, *probabilism* and *tolerance of small errors*. No machine having a unitary mechanism, a fixity of properties, an economy of connections, a certainty of output and an intolerance of errors, can successfully simulate the brain.

The Chromatrope then is to be regarded as a mechanical generator of hypotheses for exploring the nature of language. Words and concepts alike are treated as molecules of experience, the semantic particles being the atoms of which these molecules are compounded. They take the hitherto somewhat ambiguous theory of the schema forward into a form amenable to mathematical representation, mechanical simulation and testing by *micro-psychological experiment*. And they give the scientific writer a working picture of the patterns of internal radiation which his words must evoke in order to achieve semantic resonance in the reader.

Chromatrope Designs

The term Chromatrope is a generic term for a mechanism which simulates the association of two or more elements of language by means of mobile devices, selectively responsive to radiation. *Information* is coded into wavelengths. The *mental set* induced by a given context is coded into a particular selection of switches. Word-games of varying complexity can be translated into circuitry for making various selections. The two devices shown here are about the simplest possible, with circuits for *rhyming* and *alliteration*.

The model (Fig. 2) is shown set to produce a rhyme for the word 'DOG'. The code is

D = red -OG = green F = yellow

An input of red and green light stimulates chromatrope No. 1 to move along the tank emitting green

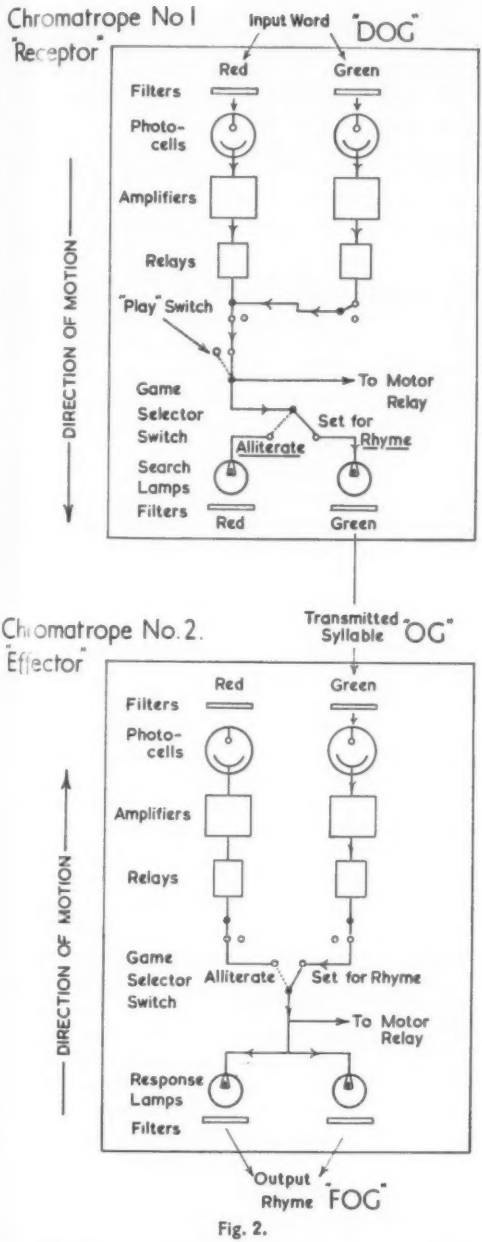


Fig. 2.

light (equivalent to asking, 'Has anyone got a word ending in -OG?'). Chromatrope No. 2 is programmed to respond to a green input by giving a yellow and green output, equivalent to saying, 'FOG'.

A change of state, corresponding to a new game, is produced by altering the switches. Alliteration is played by changing the second filter in Chromatrope No. 2 to blue (where blue is the code-sign for the sound -IRTY). The switches are then changed so that the input word 'DOG' obtains the alliterative response 'DIRTY'.

It will be obvious that more elaborate circuits in a two-dimensional system of floating models will enable an endless variety of word-games to be played. In principle a library can be simulated and the device becomes a mechanism for literature searching. A code of radio-frequencies will be used in place of colours. The mechanical mobility of the present model will be simulated by variations in an electrical parameter signifying 'semantic position'. This development is now being pursued.

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JERICHO AND THE ORIGINS OF AGRICULTURE

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Two propositions will be fairly generally accepted, that at least one of the centres in which were made the first steps in the development of agriculture was Western Asia, and that the first beginnings of settled life are closely connected with the origin of agriculture.

Any evidence of early settled communities in Western Asia has therefore an interest in connection with early agriculture. Palestine has produced evidence that is at present unique in this respect, in particular the developments which the recent excavations of the British School of Archaeology in Jerusalem have shown to have taken place at a remarkably early date at Jericho. These excavations, however, are so recent, that all the evidence derived from them is not yet fully digested or even examined. In particular, the commitments of Dr. Hans Helbaek have not yet allowed him to examine the samples which it is hoped may reveal evidence of grain and seeds. It is therefore too early to draw full conclusions from Jericho as to the beginnings of agriculture.

All that one can do at the moment is by way of inference from the history of the site. This is now firmly established by excavation, with a sequence based on absolutely certain stratigraphy. Dates for the various stages have been provided by Carbon-14 analyses. As to the fallibility or infallibility of Carbon-14, opinions are divided, but at least one can say that the results from Jericho are mutually consistent.

The earliest people of whom there is evidence at Jericho are Mesolithic Natufians related to the Natufians of the Lower Mesolithic stage in the Mount Carmel caves by the discovery of a bone harpoon-head. It has long been held by some authorities, notably the late Professor Gordon Childe,[1] that the Natufians of Mount Carmel were beginning to practise agriculture. Professor Garrod has emphasised[2] the great importance that they seemed to place on their sickles, with their elaborately carved hafts. The Natufians of Mount Carmel were cave-dwellers, and so hardly qualify as founders of a permanent settlement in the accepted sense, though at least they lived in, or re-visited, the same spot over a long period.

Perhaps one of the most important of the many important discoveries at Jericho was that the first permanent settlement there derives directly from the Lower Natufian. The level which is undoubtedly Lower Natufian Mesolithic does not produce evidence of an actual settlement. The evidence of the period was found in one area only, and consisted of a mysterious structure, a rectangular platform of natural clay, left in reserve when the clay was stripped (at the cost of some considerable labour) from the rock over the rest of the area, and revetted with a wall of massive stones. The plan of the structure, quite unlike the houses of the succeeding period, the presence in its walls of three socket-stones that might have supported totem poles, and the evidence of care in keeping the platform clean, suggest cumulatively that the structure might have been a sanctuary. The reason for the sanctuary would be the reason for Jericho itself, the abundant perennial spring which even today looks almost miraculous as it gushes out of the ground at the foot of the tell; such a water source has through the ages been regarded as sacred in the orient.

The date of this period at Jericho is given by charcoal from the destruction of the first of its two phases. A Carbon-14 analysis gaves a date of 7770 B.C. ± 200.* This is the first dating for the Mesolithic of Palestine that has been made.

* Dating by the Davy-Faraday Laboratory of the Royal Institution, in conjunction with Environmental Department of the University of London Institute of Archaeology.

Even more important is the fact that the first Neolithic of Jericho is directly derived from this Mesolithic stage. The Neolithic of Jericho is divided stratigraphically and by artifacts into three stages, Pre-Pottery Neolithic A, Pre-Pottery Neolithic B, and Pottery Neolithic. The last does not concern us, but the two Pre-Pottery stages are of great interest in the development of early settlements. Pre-Pottery Neolithic A, with which alone there is space to deal here, has now been traced back by an unbroken development of the flint and bone industry through a Proto-Neolithic stage to the Mesolithic. The Proto-Neolithic stage was found only in one area, and did not extend to excavation areas 25 m. to the south or 65 m. to the north-east. It is represented by an accumulation of 4 m. that preceded the earliest houses. Though there were no houses, there were innumerable surfaces bounded by slight humps indicating the bases of the walls of more flimsy structures. People using implements directly developed from those of the Mesolithic had settled down here, perhaps at first seasonally, but eventually permanently. They must therefore have been assured of their food supply, though our evidence is as yet too slight to say whether this was purely dependent on nature, on wild grains and on hunting wild animals, or whether agriculture and the domestication of animals had begun.

But the assurance of food supply led to the next stage. Soon after the spread of this Proto-Neolithic stage, with slight structures, the stage comes of solid structures, round houses with substantial walls, built of plano-convex bricks hog-backed in section, spreading over an area of something like 10 acres (the exact area cannot be established, since it is truncated on the east side by the modern road). Following this comes the most remarkable evidence of the growth of the community, the building of a great town wall, traced on the north, west and south sides of the mound, and associated in at least one place with a stone-built tower 40 ft. in diameter at the base, and surviving to a height of 30 ft.

There is here therefore evidence of two important facts; firstly a settlement of some 10 acres in extent, closely built up on the evidence of the five widely separated areas in which excavation reached these levels, and capable of housing some two to three thousand persons on present oriental standards; secondly, a community organisation that could undertake the building of these massive and imposing defences. A date for this stage is given by a Carbon-14 dating of a level late in the history of the defences of 6850 B.C.

It is on the development of this settlement, on a scale worthy of the title of town, that the development of agriculture can be inferred. The inhabitants of a settlement of this size could not have been supported on natural resources alone. It can be taken as a reasonable presumption that it was the spring at Jericho that attracted the first settlers. Even today, the Jordan Valley is arid and uninviting away from those areas reached by the waters of the various springs and streams; only modern experiments in the sinking of wells have extended the area of cultivation beyond the limited stretches within reach of the natural sources of water. Within the area watered by the spring at Jericho, it can be presumed that wild grasses grew reasonably abundantly, independent of the seasonal rainfall. But this area would not, of its own accord, have spread over many acres, and the grain from the wild grasses in this limited area would not have added much to the food of a sizable population.

The stages in progress of food supply, can only, on the evidence at present available be guessed at on the archaeological evidence of the development of the settlement. In the Proto-Neolithic stage, this settlement was restricted in size, though permanent in character. On the evidence of the Carbon-14 datings for the preceding and succeeding stages, it may have covered a period of some five to seven hundred years. Since the progress in the succeeding period is so rapid, it is hard to avoid the conclusion that during this space of time the inhabitants of Jericho followed up the beginnings which may have been made by their ancestors on Mount Carmel, and begun to improve on the productivity of nature by primitive agriculture.

This is presumption only. What is not presumption, but hard archaeological fact, is that progress from this stage is so rapid that it must have been based on a sound foundation. The expansion of the light structures of the Proto-Neolithic stage beyond the original small nucleus is immediately followed by the development of solid houses over the whole ten acres of the subsequent settlement, and the spread of solid structures is rapidly followed by the building of the elaborate and grandiose defences. Reference has already been made to two significant

points in this connection, the size of the settlement and the evidence of community organisation. A sedentary population of the size to be presumed (and it is undoubtedly fully sedentary at this stage) could not have been supported on hunting and the limited wild grains available in the area watered by the spring in its natural state. The population was certainly carnivorous, for many animal bones have been recovered from the contemporary deposits. The identification of these bones is in progress, but it is doubtful whether there are sufficient criteria to decide if the animals were wild or domesticated. But a purely carnivorous population is not sedentary, for pastoralists are at least semi-nomadic. It is therefore a reasonable assumption that the population of a firmly established site such as Jericho was tied to its fields.

From this stage, one is forced further. The present oasis of Jericho covers a large area. But this area is only rendered fertile by a complicated series of irrigation channels. A remarkable contrast is provided by photographs of Jericho in the mid-nineteenth century, when only a miserable village existed on the site, and the whole area of the present oasis was arid and covered with rough scrub. The potentialities of the spring can only be exploited by irrigation, and only with irrigation can the area support a sizable population. Irrigation requires an intricate organisation, and above all a controlling power to enforce the organisation. This sort of thing is an intangible which the material evidence, which is all that archaeology can observe, does not record. But what archaeology can record is other evidence of community organisation, and this at Jericho is abundantly clear in the grandiose defensive system. It is therefore a reasonable presumption that by the time the settlement at Jericho had spread to its full size of 10 acres, a system of irrigation had developed to supply its agricultural needs, and that the communal organisation required for the irrigation was also responsible for the defences.

Factual evidence of the irrigation will never be found, for modern irrigation and agriculture in the oasis will have destroyed it. But finds within the town area can best be explained as associated with an irrigation system. The massive stone tower backing on the defences on the west side of the mound was in its first stages free-standing. In its second stage, a series of curious structures were built against it, quite unlike the houses of the period. Their walls survive to a height of 3·12 m., and the only opening found between them was a channel 45 cm. high, through which ran lines of water-laid silt. The only obvious explanation of these enclosures is that they were water-tanks, in which was collected rain water (or water transported by hand). From the relative levels, they would have provided a head of water 7·90 m. above that of the spring, and therefore would have irrigated land to the west and south of the settlement, inaccessible to the waters from the spring.

Earliest Jericho, therefore, provides evidence of the growth of a settlement that by *c.* 7000 B.C. had reached a size that makes it as certain as inference can that it was supported by an efficient system of agriculture, and the evidence that a high degree of community organisation had been evolved suggests that this efficiency was increased by irrigation. It now remains to be seen if any of the samples will provide evidence for actual cutivated plants.

References

1. *New Light on the Most Ancient East*, 1952 edition, p. 29.
2. *Proc. of the British Academy*, **43**, p. 216.

CRYOTRONS AND OTHER HIGH-SPEED SUPERCONDUCTING COMPUTER DEVICES

By Dr. J. M. LOCK *Royal Radar Establishment, Great Malvern*

Introduction

The operations which take place in a digital computer are of two kinds, arithmetical and logical, and deal respectively with numbers and instructions, but both can be conveniently represented by means of the binary code so that only two symbols, 0 and 1, are needed. This simplification enables the computer engineer to work with devices capable of existing in just two well-defined states, and it is such bistable devices which are the basic bricks from which modern high speed machines are built (this is not to say, however, that a good deal of mortar is not also needed!).

The properties which are of importance in considering whether a particular type of bistable device is going to be a useful one are first that it should have adequate discrimination between the two states, and second that it should be capable of switching rapidly from one to the other. Let us consider straight away the use which can be made of the properties of superconductors.

Superconductivity

Certain metals when cooled to a very low temperature, usually within a few degrees of absolute zero, quite abruptly lose every trace of their electrical resistance. They are said to become superconducting, and the temperature at which this occurs is known as the transition temperature, T_c, of the superconductor. At any temperature below T_c it is found, however, that it is possible to restore the normal resistance of the metal by the application of a magnetic field larger than a certain critical value, H_c, which increases from zero at the transition temperature to perhaps a few hundred gauss at absolute zero. For chemically and physically pure metals the H_c versus T plot, or 'critical field curve', is a perfectly definite characteristic of the superconductor in question. (See e.g. D. Shoenberg, *Superconductivity*, 1952.)

Because electric currents give rise to magnetic fields it follows also that a large enough current in a superconducting wire can itself restore resistance in it, so that we can speak of the critical current of the wire. Except for exceedingly thin wires and films (of the order of 10^{-5} cm. linear dimensions) the critical current of a circuit is just that current which will produce the critical field at some point on the surface of the superconductor.

The electrical resistance of a superconductor is thus a strongly non-linear function either of the applied magnetic field or of the current through it, remaining zero up to some critical field or current and then rising, though not necessarily sharply, to its full normal value at higher fields or currents. It is this non-linearity in resistance which has made possible the construction of bistable superconducting devices.

The Cryotron

The restoration of resistance in a superconducting wire by a magnetic field was made the basis of the first superconducting device, developed by D. A. Buck (1956), and called by him the cryotron. Although this device in its original form was not very fast, its switching speed being limited to a few thousand cycles per second, it exemplifies most of the principles involved in other faster superconducting devices and so is worth describing in some detail. It consists of a superconducting gate wire, usually of tantalum ($T_c = 4{\cdot}4°$ K.), whose resistance is controlled by the magnetic field of a coil wound round it, made of a superconducting wire with a much higher transition temperature, such as niobium ($T_c = 8°$ K.). Typical dimensions are shown in Fig. 1. The

critical field of the gate when operating in a bath of liquid helium boiling at atmospheric pressure (about $4{\cdot}2°K$) is roughly 40 gauss, and the control current needed to restore its normal resistance (only about 0·01 ohm) is about 300 mA. The control winding remains superconducting up to a much higher current than this, and in fact its resistance is zero under all normal operating conditions.

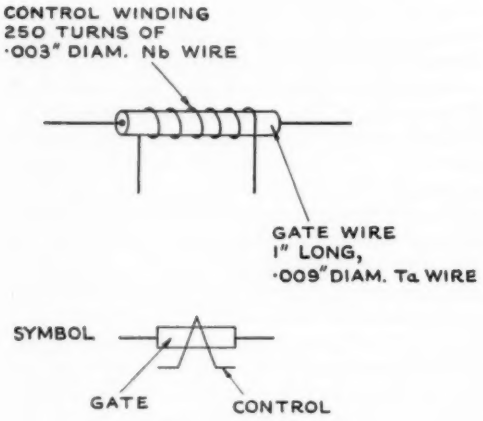


Fig. 1.—The Cryotron.

The important feature of the cryotron is that, provided a certain condition is fulfilled, the gate current of one cryotron can be used to control a second identical one. This condition is, of course, that the critical current, i_G, of the gate wire shall be greater than the current, i_C, in the control winding needed to restore the gate resistance. These two currents are related to the critical field, H_c, of the gate wire by the relations: $i_G = \frac{1}{2}rH_c$, $i_C = H_c/4\pi n$, where r is the radius of the gate wire, and n is the number of turns per cm. of the control winding. The above condition therefore reduces to: $2\pi nr > 1$, and the quantity $2\pi nr$, denoted by K, is called *the current gain* of the cryotron. In the cryotron shown in Fig. 1, K is about 7. Provided the current gain is greater than unity, cryotrons can be used in logical circuits without the use of additional amplifying devices.

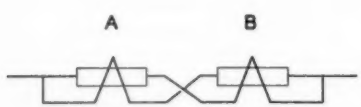


Fig. 2.—The Flip-Flop.

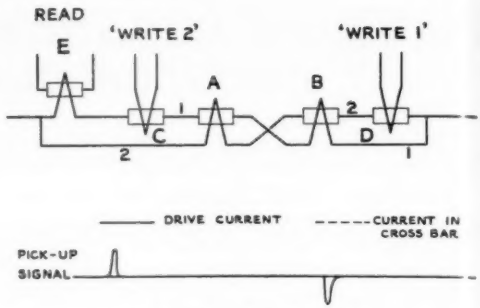


Fig. 3.—Complete Flip-Flop.

The simplest such circuit consists of two cryotrons connected in parallel with the gate of one in series with the control winding of the other, and constitutes a bistable element or flip-flop (Fig. 2). A current supplied externally can flow either through gate A and control winding B, thus holding gate B resistive, or through gate B and control winding A, thus holding gate A resistive. As it stands, however, our flip-flop has no means of controlling the current path; to do this we need two further cryotrons, C and D (Fig. 3), each with its gate in series with one of the two paths, whose control windings act as 'write-in' circuits. Furthermore, to sense the state of the flip-flop we need at least one more cryotron, E, with its control winding in series with one of the paths, so that its gate acts as a 'read-out' circuit. The complete flip-flop therefore consists of five cryotrons.

The time taken to switch the current in a cryotron flip-flop from one path to the other depends on the rate at which the current decays when resistance is inserted in the first path by means of the 'write-in' pulse. This decay rate is determined by the self-inductance, L, of the control winding and by the normal resistance, R_G, of the gate wire, and it turns out that the complete switching process occupies a time of about $7L/R_G$. Although the dimensions of Dr. Buck's cryotrons are very small, switching still takes about 150 microseconds, and it seems probable, therefore, that the wire-wound cryotron will never be a serious competitor

in the field of ultra high speed computers (switching speeds of less than 1 microsecond, say). An even more serious limitation to the speed of this type of cryotron is set by the heating which inevitably occurs during the 'write-in' pulse, when resistance is first inserted into the arm of the flip-flop which is still carrying current. Since the rate of heating is initially $R_G i^2$, where i is the current carried by this arm, and since it continues for a time of about L/R_G, the total heat generated is about Li^2. This heat causes warming of the gate wire, and it is found in practice that, because the maximum permissible temperature rise of the tantalum is only about 0·1° K., the switching frequency of the flip-flop is limited to only about a thousand cycles per second.

The 'Strip Cryotron'

This brings us to a discussion of the possible ways of improving the performance of superconducting devices like the cryotron. It seems probable that the same two factors, namely the L/R time constant of the circuit in the normal state, and the Li^2 heat generated per 'switch', will limit the speed of any such device, and wire-wound cryotrons are slow because the multi-turn control winding makes L large, while for a gate wire of reasonable diameter R_G is small—less than 0·01 ohm for a typical tantalum gate. The use of thin evaporated films for both gate and control of the cryotron should clearly effect a considerable improvement, for by making one dimension of the device very much smaller, a large reduction of the L/R ratio should be achieved. This idea has been tested in the 'strip cryotron' at the I.B.M. laboratories in America, in which the basic circuit consists simply of two evaporated superconducting strips crossing one another at right angles, and insulated from each other by an intervening evaporated film of silicon monoxide. The gate is of tin ($T_c = 3{\cdot}73°$ K.), and the control strip of lead ($T_c = 7{\cdot}2°$ K.). The chief difficulty seems to be the avoidance of structural imperfections in the evaporated films which lead to a marked reduction in the critical current of the gate strip, and thus to a lowering of the current gain. Using the utmost care in controlling the evaporation conditions, and with the dimensions shown in Fig. 4, a maximum current gain of 4 has been reported (D. R. Young, 1959), whereas the theoretical value for the gate/control width ratio used should be about 30.* The lead ground plane shown in the figure serves an important purpose. By confining the magnetic field due to the current in both the control and gate strips to the narrow region between the strip and the plane it greatly reduces the self-inductance of each circuit (a figure of 10^{-11} henry per cm. length of control strip is claimed), and for the same reason it makes the current distribution in the gate strip more uniform and thus raises the critical current of the gate. Figures for the high speed performance of this type of cryotron are not yet available, but it is possible to estimate a rough value of the L/R constant of about 10^{-8} sec. Since the self-inductance is extremely small it is unlikely that the Li^2 heat generated will be a serious limitation, and the 'strip cryotron' should therefore be capable of operating at switching frequencies of many megacycles per second.

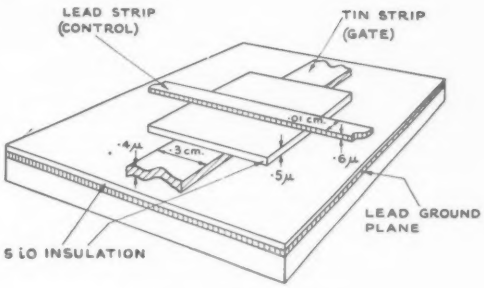


Fig. 4.—The Strip Cryotron.

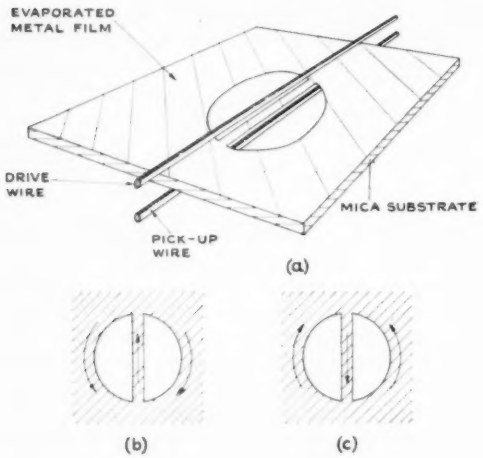
The Crowe Element

A second type of superconducting device based on a somewhat different principle will now be described, which acts as a passive information storage element only, and not, like the cryotron, as an active logical element. It makes use of the possibility of setting up persistent currents in a superconducting circuit, and using the direction of these currents to represent the two states required for information storage. It was invented by J. W. Crowe (1957), and has now been studied in some detail both at I.B.M. in America, and

* Note. More recently (May 1960) these difficulties have largely been overcome, and current gains practically equal to the theoretical values attained.

also in this country at the Royal Radar Establishment and at the Services Electronics Research Laboratory.

The Crowe element consists of a thin vacuum-evaporated film of tin or lead, of the shape shown



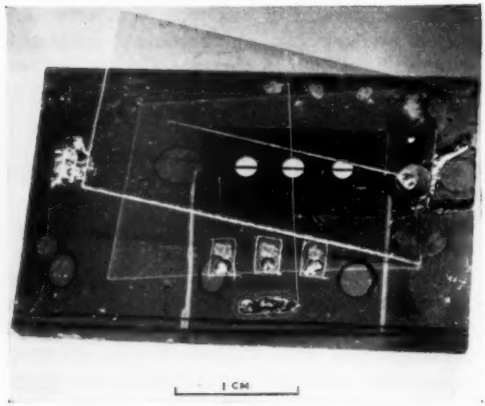


Fig. 5.—The Crowe Element.

in Fig. 5*a*, on a glass or mica substrate. The two states of the element are represented by currents flowing in the directions shown in Figs. 5*b* and 5*c*, and are set up by current pulses of opposite polarity through the drive wire, which is closely linked inductively with the superconducting circuit. Changes of state of the element are detected by means of the pick-up wire beneath the crossbar. The drive and pick-up wires can themselves be made of thin evaporated strips of metal separated from the superconducting film by evaporated layers of insulator, and in this way their inductive linkage with the crossbar is made as close as possible. Under these circumstances, as long as the film itself remains entirely superconducting, any change in the drive current induces a current in the film which prevents any change of flux through the D-shaped holes in the circuit, so that no voltage is induced in the pick-up wire, and no change of state of the element occurs on removal of the drive pulse. However, if the drive current is increased sufficiently, the induced current in the crossbar reaches the critical current, i_c, above which normal resistance reappears in the film. As soon as this happens the flux through the D's changes, a voltage signal is induced in the pick-up wire, and on removal of the drive pulse the element will have changed its state. The value of the critical current in the crossbar depends on its width and thickness, and on the temperature of the surrounding helium bath. Work on evaporated tin elements at R.R.E. has shown that with a crossbar 0·2 mm. wide and about 2000 Å in thickness the critical current can be varied over a convenient range from zero to about $\frac{1}{2}$ amp. as the temperature of the helium bath is lowered from the transition temperature of tin, 3·7° K., to about 2° K. The length of the crossbar in this case was 2 mm. A set of three of these elements are shown in the photograph. The drive wire is tilted for greater clarity.

Mode of Operation

The mode of operation of the element is shown in greater detail in Fig. 6, where the drive current, the crossbar current and the pick-up voltage are plotted against time for a typical sequence of drive pulses. At stage A we see how a positive drive pulse leaves a positive persistent current i_p in the superconducting film; the initial rise in drive current is accompanied by a rise in the crossbar current in the opposite sense to keep the flux through the D's just zero (OP in Fig. 6). As soon as the crossbar current reaches its critical value, $-i_c$, at P, resistance returns in the crossbar and the current in it drops (PQ). During the

trailing edge of the pulse the crossbar remains superconducting, and to keep the flux through the D's constant again the crossbar current must 'mirror' the change in drive current, so that a persistent current is left in the film at R. During the stage PQ when the crossbar is resistive the penetration of flux through the D's is accompanied by a voltage signal on the pick-up wire as shown.

If now a second identical positive pulse B is applied it is easily seen that the crossbar current never becomes critical; no flux change through the D's can take place, therefore, and no voltage signal is induced in the pick-up wire. The persistent current remaining after the pulse is the same as before. Application of a negative pulse, however, as at C, causes the crossbar current to reach $+i_c$ at S and after removal of the pulse a negative persistent current is left in the film. A negative

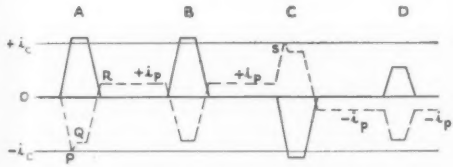


Fig. 6.—Mode of Operation of Crowe Element (Schematic).

voltage signal is induced in the pick-up wire on the leading edge of the drive current pulse.

The Crowe element thus has all the properties required for storage of information. We can represent a '1' by a positive and a '0' by a negative persistent current, when the positive drive current becomes a 'write 1' pulse, and the negative drive current an 'interrogate' or 'write 0' pulse. The interrogate pulse will yield a pick-up voltage only if the element is in the '1' state. This pulse will leave the element in the '0' state, whatever its previous state, so that, used in this way, read-out is destructive.

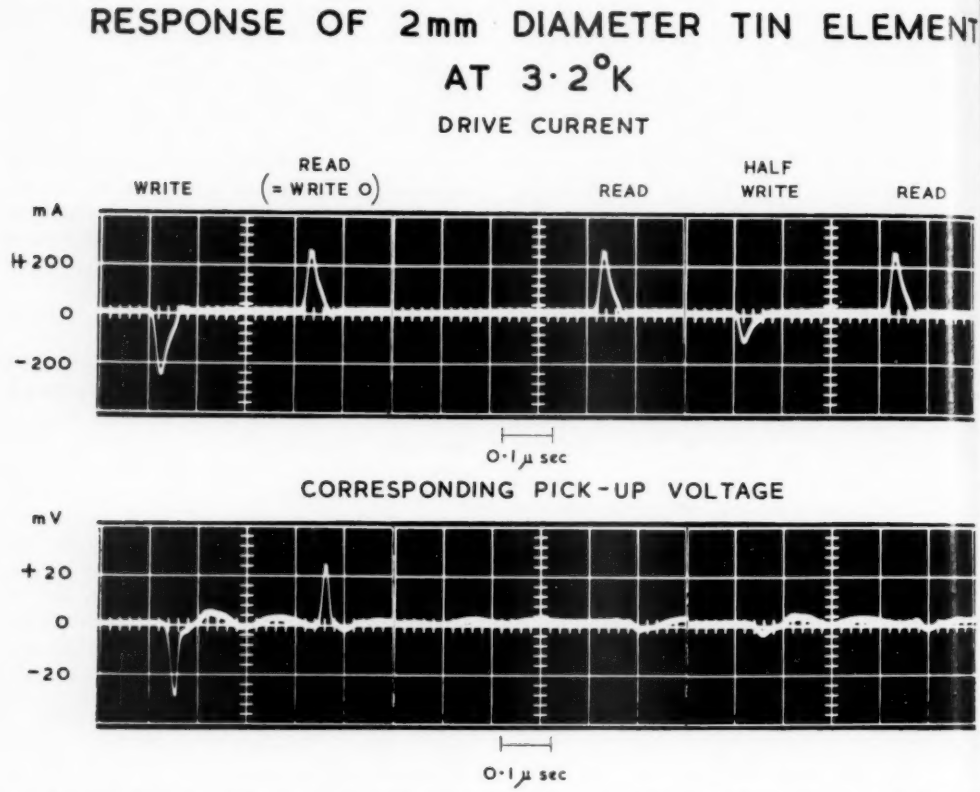
It is not difficult to see that if the amplitudes of the 'write 1' and 'interrogate' pulses are suitably chosen, then half-level pulses, positive or negative, will not disturb the state of the element. This is shown at D in Fig. 6 for a 'half-write' pulse. Thus coincident current working, using two drive wires for each element, can be used for selection of elements in a square array. This is clearly a most important property if a really large computer store is to be constructed using these devices.

The actual response of the tin elements used at R.R.E. is shown in the oscilloscope traces of Fig. 7, where drive current pulses of a rather triangular shape, about 50 mμsec. in width across the base, have been used. The disappearance of the pick-up signal in the absence of a full-level write pulse preceding the read pulse is clearly shown. (The polarity of 'write' and 'read' are interchanged in this photograph as compared with Fig. 6.)

Speed of Operation

The switching speed of the Crowe element is governed by two factors. In the first place the rate of decay of the current in the crossbar when the latter goes resistive depends on its normal resistance, R_n, and on the self-inductance, L, of the superconducting circuit. Typical values for elements of the size mentioned above are $R_n \sim 0{\cdot}1$ ohm and $L \sim 10^{-9}$ henry so that $L/R_n \sim 10^{-8}$ sec. Second, as soon as the crossbar is driven into the normal state, heat is generated in it, and its temperature rises, thus decreasing momentarily the value of the critical current. The trailing edge of the drive pulse must be delayed until the critical current has recovered at least nearly to its full value, or in other words until the temperature of the crossbar has dropped to the bath temperature once more. This thermal recovery time depends on the metal and on the substrate material, and experiments at R.R.E. with tin elements on a mica substrate, using switching pulses down to 5×10^{-9} sec. in length, have shown that it can be as short as 10^{-8} sec. The amount of heat generated each time an element is switched is roughly Li_c^2 which, with $i_c \sim 300$ mA, is about 10^{-10} joule, and it is probably quite feasible to switch such an element at a frequency of 20 Mc/sec., when the average power dissipation would still be only 2mW. The voltage signals obtained on switching are about 20 mV.

These memory elements thus have all the necessary qualifications for a really large and fast computer store, with a random access time of less than 10^{-7} sec. for write-in and destructive read-out. They are more than ten times as fast as ferrite cores for this purpose, but several formidable problems remain to be solved before a store,



NO PICK-UP SIGNAL IS OBTAINED UNLESS THE ELEMENT CHANGES FROM ONE STATE TO THE OTHER. TO INTERROGATE, A 'WRITE 0' ('READ') PULSE IS APPLIED. IF A '1' IS STORED A VOLTAGE PULSE APPEARS ON THE PICK-UP WIRE. BUT IF A '0', NO PICK-UP SIGNAL IS OBTAINED. A HALF LEVEL WRITE PULSE IS INSUFFICIENT TO SWITCH THE ELEMENT AND THEREFORE COINCIDENT CURRENT SELECTION, USING TWO DRIVE WIRES, IS POSSIBLE.

Fig. 7.

containing perhaps a million or so elements, can be successfully constructed.

Problems of a Low Temperature Computer

First it must be emphasised that, whereas the cryotron, because it has current gain, is in principle capable of fulfilling the requirements of all the logical elements in a computer as well as those of the store, so that the whole computer, apart from its input and output, could work under liquid helium, this is not true of the Crowe element by itself. It is a memory device only, and must work in conjunction with other active elements. Even making use of coincident current drive wires, a large store of Crowe elements will require too large a number of selection circuits to be brought up to room temperature from the helium bath. Selection circuits will therefore be needed which are capable of operating entirely in the liquid helium. Semiconductor devices can probably be

used for this purpose, and indeed it is quite likely that these will enable not only the necessary selection and gating to be carried out at low temperatures, but even the arithmetic and logical functions of the computer, so that, just as with the cryotron, one may envisage the entire high-speed circuitry operating in liquid helium.

Crowe elements themselves with their associated drive and pick-up circuits are certainly compact enough to allow a large store to be assembled in a reasonable space. Ten million 'bits' need occupy little more than a cubic foot. Much work needs to be done, however, to ensure that the properties of the individual elements are sufficiently uniform, and this needs very careful control of the evaporation process. Furthermore the associated circuitry must be capable of transmitting very short pulses without distortion, in order to make full use of the inherently high speed of the elements. Luckily the planar form of the elements lends itself to an arrangement of drive and pick-up wires as strip transmission lines, which should be ideal for this purpose.

Finally, the low temperature requirements of the store would probably best be met by the use of a small built-in helium liquefier of the closed-circuit type, designed so that on starting up the machine the correct working temperature would automatically be maintained. The liquefaction rate need not be high, since the total power dissipation even in a store of the size considered, working at 20 Mc/sec., and assuming that 100 elements are switched at once on the average, will only be about 0·2 watt; the additional heat dissipation due to conduction down leads might perhaps increase this figure to 1 watt, so that possibly 2 litres per hour of liquid helium would be required during operation. This will not present a serious engineering problem.

It is worth noting that this type of store may be capable of operating within a factor of ten or so of the maximum possible speed of random access, set by the limitation of the velocity of light. Assuming that any store of reasonable size will require access lines at least a foot in length, then the access time must correspondingly be at least a millimicrosecond. Since it is possible that the superconducting store may achieve a random access time of 10 millimicroseconds, it may well come within striking distance of this ultimate goal.

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JOHNE'S DISEASE—A CHALLENGE TO AGRICULTURAL RESEARCH

By Dr. DEANS RANKIN *Agricultural Research Council*

Each year some 30,000 dairy cows die, or are culled from the national herd, as a result of Johne's disease. When the losses incurred in beef cattle are added to this it would appear that the dairy farmers and beef breeders in Britain are between them sharing an annual loss of £3,000,000 to £4,000,000. Although this sum is about thirty times the amount likely to be paid out in compensation in an average year as a result of losses due to foot and mouth disease little is heard of Johne's disease because, even although it is a killer, it is not spectacular in its onset. Rather is it an insidious disease with a very long incubation period (usually measured in years) affecting only one or two animals in a herd at any one time. On an infected farm, however, cases tend to recur year after year and as the loss is often total (the carcase being worthless and the hide value swallowed up in the cost of transport to the knackery) in contrast to losses due to, say, infertility or mastitis, Johne's disease can be a very serious matter to the individual farmer. It is, in fact, a good example of the type of disease problem which is more and more worrying the farmer and the veterinary surgeon today, *viz.* the insidious disease affecting only a few animals at any one time but which occurs year after year without apparent explanation.

Johne's disease is an infectious enteritis of ruminants and that, as far as British agriculture is concerned, means cattle, sheep and goats. It is caused by a small bacterium closely related to the tubercle bacillus and called *Mycobacterium johnei* after Johne, a German physician, who first saw it sixty-five years ago, in 1895. Like the tubercle bacillus, *Mycobacterium johnei* has a tough wax coating which enables it to survive for long periods on grass, for example, or in water. It is, however, an obligate parasite and does not multiply in nature outside the body of an infected animal. Affected cattle, sheep and goats are therefore the reservoirs of infection and they void countless millions of organisms in their faeces.

Although it is known that some calves become infected while in the uterus, in the majority of cases infection is believed to occur by way of the mouth as a result of swallowing grass, water or milk contaminated with infected faeces.

The constant site for lesions to develop is in the intestine, which becomes so damaged that its function becomes impaired and food is passed through with little digestion or absorption having taken place. Diarrhoea and extreme emaciation result and these are the classical symptoms of the disease (Fig. 1). There is no effective treatment and once clinical signs are present, death is the usual outcome.

Johne's disease has not been scheduled and therefore there is no obligation on the stock-owner or veterinarian to make any official notification of its presence. As a result there is no really accurate information relating to its incidence. Various surveys, however, have been made and these suggest that 1 per cent of our adult dairy cattle will die of Johne's disease this year and that 25 per cent of the cattle received at the knacker's yards will be showing evidence of the disease. It is also known that about 20 per cent of adult cattle harbour the causative organism without appearing to be ill.

We have already noted that the disease is incurable and ultimately fatal. From the control point of view it has other unattractive attributes. For example it has a very long incubation period which is seldom less than one year and may often be five or even ten years. The causative bacillus is not easy to isolate and grows very slowly on artificial media, from one to six months being necessary for its primary isolation. No small laboratory

Fig. 1.—A case of Johne's disease showing a considerable degree of emaciation. Fluid faeces is being passed in an unbroken stream.

animal has proved to be susceptible to the disease and consequently experiments have to be carried out in cattle, sheep or goats which are, relative to mice and guinea-pigs, costly to buy, costly to feed, and their accommodation presents a problem. Furthermore, the known methods of diagnosis are not always reliable and it is often only in the terminal stages that the disease can be diagnosed with certainty. Lastly our present vaccine has unfortunate side effects which cause reactions to tuberculins and so interfere with the proper interpretation of the official tuberculin test of the Ministry of Agriculture.

There then is our challenge. How is it being met?

After the discovery of the organism the next obvious step was to grow it in the laboratory. For fifteen years, however, Johne's bacillus defied all attempts to isolate it. Then in 1910 Twort and Ingram reasoned that the bacillus was lacking in some substance necessary for its growth and which it could not synthesize from simple media. They reasoned that as the related tubercle bacillus would grow on simple media it must possess this power of synthesis. They therefore added dead tubercle bacilli to the medium and grew *Mycobacterium johnei* for the first time. Today it is still necessary to add dead acid-fast bacilli or their metabolic products to the medium before *M. johnei* can be isolated in primary culture.

After the isolation of *M. johnei* it was quickly discovered that the disease could not be set up in laboratory animals, nor indeed could it be readily set up in the host species; nevertheless, during the next twenty-five years, a considerable amount of knowledge of its pathology was acquired from the study of affected animals. However, very little experimental work, as we understand the term, was carried out because of the high cost of using large animals and the uncertainty of infecting them. Because of the lack of facilities, research workers gradually lost interest in the disease, until in the early 1930s the British scientists seriously engaged in its study could be counted on the thumbs of two hands. Further progress had to await the advent of something entirely new in veterinary research planning.

Between 1930 and 1935, informed opinion was turning towards the belief that in many fields of veterinary research the acquisition of further information was going to be dependant on the ability to carry out experiments on the farm animal under properly controlled conditions. To this end, the Agricultural Research Council decided to establish a Field Station at Compton. The project was started in 1937, but only the main block was completed before war put a stop to building. The vast Isolation Compound, which is the main feature of the Station, could not be started until the war was over and thus was not completed until 1949. This Compound is capable of housing in isolation more than 500 cattle at any one time. Thus for the first time in any country, properly controlled experiments can be carried out on

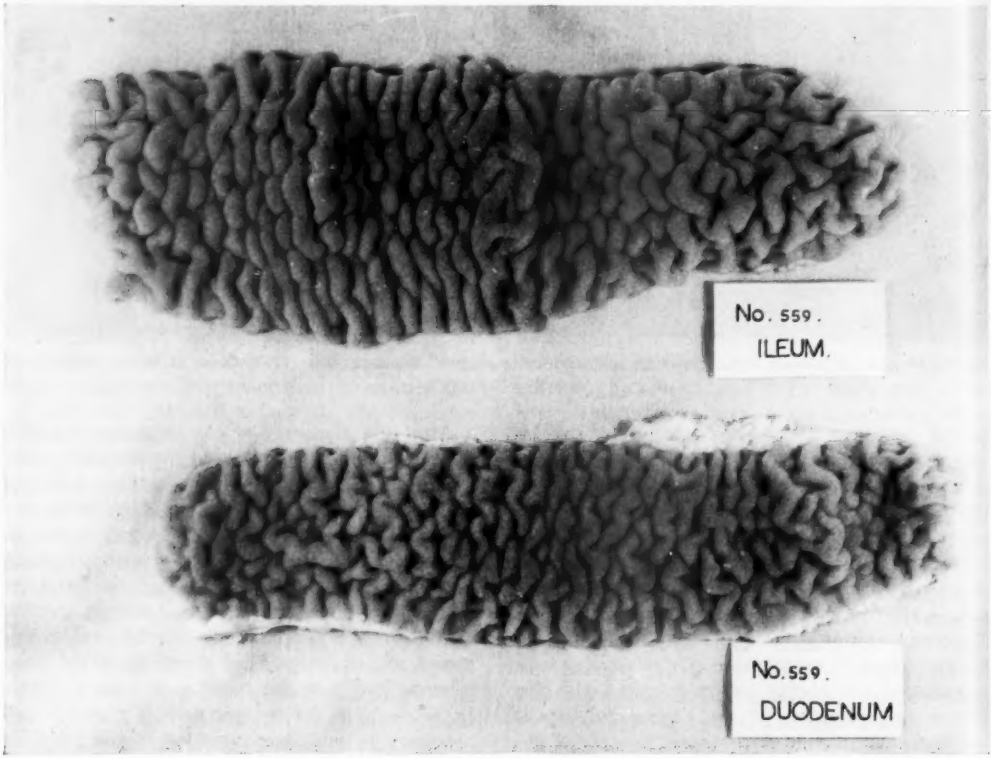


Fig. 2.—Portions of the small intestine of an advanced case of Johne's disease. The marked thickening and tight convolutions of the mucous membrane are characteristic of the disease.

Fig. 3.—Panorama of the Isolation Compound at Compton. Some of the 22 Isolation Units and the central slaughterhouse and incinerator can be seen. The whole Compound covers about 16 acres.

sufficiently large groups of cattle to give statistically valid results. Workers on other bacterial diseases are often compelled to use hundreds of mice or guinea-pigs before acceptable conclusions can be reached, and now, when necessary, we can do the same using cattle. The cost will be very much greater but we must not expect a commensurate increase in the information yielded. In the eyes of the statistician one cow equals one mouse.

These facilities have allowed us to pick up the threads of Johne's disease investigation and recommence our studies, this time as a continuous, progressive story and not as a sort of *ad hoc* disconnected piece of work. Before World War II began, there was already a considerable quantity of information suggesting that there was a difference in susceptibility between the young calf or lamb and the more mature animal. After the war, in a series of experiments it was shown that often 100 per cent of a group of one-month-old calves would contract the disease as a result of an intravenous injection of Johne's bacilli. At the same time, it was demonstrated that the adult cow is peculiarly resistant to such inoculations. (Only one of twenty-five adult cows exposed to *M. johnei* in various ways has so far contracted the disease.) It seems that this resistance to the clinical disease is in some way associated with maturity and not with the presence of an antibody resulting from previous exposure to the specific antigen or an allied one.

Satisfied that the calf was the animal of choice we now started to titrate the infective dose in one-month-old calves. The titration was carried out in three annual stages, each timed to coincide with

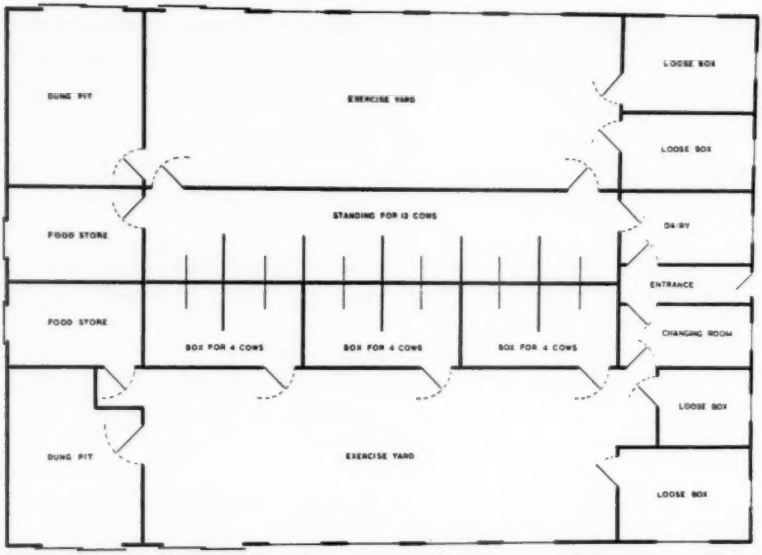


Fig. 4.—*Plan of an Isolation Unit.* The unit is divided by a central wall on one side of which an arrangement suitable for a group of 10 or 12 cattle is shown. On the other side the unit is constructed to accommodate groups of 4 cattle.

our spring flush of calves, and at the end of five years we were able to sum the results and this is what we found:

INTRAVENOUS DOSES OF *M. JOHNEI* FOR CALVES

Dose	*No. Positive*	*No. Negative*	*Percentage Positive*
100 mg.	14	2	87·5
10 mg.	10	6	62·5
1 mg.	4	12	25·0
0·1 mg.	0	10	0·0

We also found that we were producing the disease at a much younger age (1 year) than occurred in naturally occurring cases. ($2\frac{1}{2}$ to $4\frac{1}{2}$ years). At first sight, this appeared to be an advantage as it would shorten experiments considerably, but on reflection I am not sure that this is a good thing. As well as shortening the in-incubation period, the method was producing animals stunted in their growth. This stunting was a disappointment as it is a feature not usually seen in the naturally occurring disease. At first it was thought that this stunting was the result of damage to the lung resulting from the intravenous inoculation, but this is not the case. Histological examination of the lungs shows remarkably little effect of the passage of the bacilli through the lungs, and it is now believed that the stunting is due to early damage to the intestine before the animal has reached its full stature.

For this and other reasons it was decided that the oral route of infection might be the better one for our purpose and so last year an experiment was set up to titrate an oral dose of *M. johnei* in calves. Again the experiment is being carried out in three parts, but a slightly different dose range is being used. The experiment is planned to run for another four years when we hope to be rewarded with a series of doses, the precise effect of which will be known. Having determined the best test dose for our purpose we shall be in a position to test vaccines and therapeutic agents in a proper experimental fashion instead of going straight to the field with them as we have to do at present.

Because of the long incubation period of the disease, progress is inevitably slow, but now that the facilities for large-scale experimentation on cattle are available there seems no reason to doubt that a solution to the problem of Johne's disease will eventually be found.

THE REORGANISATION OF SECONDARY EDUCATION

By G. H. BANTOCK *University of Leicester*

Why is there so much fuss at the moment about the reorganisation of secondary education? We ought, to start with, to try to understand some of the social forces which have produced the present ferment. High on the list of influences I would place the current struggle for status. The nineteenth and early twentieth centuries have seen, to all intents and purposes, the final dissolution of the old hierarchical society based on birth and inheritance of the land; though an 'Establishment' of a sort persists, it is of a more fluctuating character than that of the old aristocracy. Industrialisation has demanded technical expertise, and commercial enterprise has led to the evolution of the business corporation, with its opportunities of management and its need for skilled technical assistance; the day of the gifted amateur is largely over. In government, the spreading demands of bureaucracy have likewise made calls for a higher standard of education, of a certain sort, and at the same time provided incentives to seek further qualifications in the general struggle for higher status. There has been a coincidence between the working and lower middle classes' realisation of the potentialities of qualifications in terms of better jobs, and what is called the 'need for educated manpower'—revolting phrase!

This demand for a trainable technical expertise, then, rather than for those qualities which come from having been nurtured within a certain environment, where the accomplishment of skills goes along with an induction into a way of life, has done a great deal to bring about the educational revolution of our times. The need for experts, in this sense, has meant that anyone of the necessary intellectual capacity can achieve both a high degree of 'expertness' and the success which our competitive society so esteems. The rootless, socially mobile intellectual is the prototype of the new man of the technological age. For it is partly the nature of the 'job' which has permitted this sifting of ability such as we now witness. The 'job', that is to say, has become something *sui generis*, abstracted as a 9 to 5 phenomenon (or whatever hours are worked), largely detached from the 'before' and 'after' of home and family—indeed, usually opposed to 'leisure'. In this, modern education produces and is intended to produce something quite different from that nurtured by the mediaeval institution of apprenticeship, the monastic school or the renaissance training in 'courtesy' provided in the great house. In such a situation, the notion of 'equality of opportunity' comes to seem important, partly at least, because in the terms in which modern education is conceived, some degree of 'equality' becomes feasible. Brains—functioning in certain specific ways—are what count; and there is no guarantee that any one class of the community has a monopoly of such a commodity. Therefore everyone must have his chance.

One of the most powerful influences, then, behind the recent cry for secondary reorganisation has been the feeling that, because of defective methods of selection at 11+, some children are not getting the chances their subsequent performance would seem to warrant; this is unfair to them and wasteful for the country, which needs all the 'brains', defined as I have indicated, it can get: the criterion operative here is one of social need. And, of course, given the assumptions on which the whole present-day concern for education is largely based, there is a good deal in this. At the same time, it is interesting that, at a moment when the 11+ examination has been so under fire, the prestige of other exams has not suffered to anything like the same degree. Indeed, other examinations, particularly that of the

Ordinary level of the General Certificate, are extensively quoted as evidence for or against the success of the selection tests. Furthermore, many secondary modern schools are introducing G.C.E. courses and other examinations as incentives to their pupils and as a means of raising their own prestige, even though it is likely that the G.C.E. results are as open to criticism as the 11+ is and for some, at least, of the same reasons. This alone would suggest that there are powerful forces behind the 11+ rumpus other than a concern for the predictive accuracy of examinations.

Certainly, another influence which has played a considerable part in the earlier development of the comprehensive school is the egalitarian one. The advocate of social harmony has seen an ally in the common school. I need only mention the theoreticians of the London School Plan who urge that, 'It is a matter of first-rate importance for modern society that life in school should promote a feeling of social unity among adolescents of all kinds and degrees of ability.' In a sense, these may be the vestigial remains of a conception of education which looked to the educative agency not simply to train for function, or as a vaguely liberalising influence, but to induct into a way of life. But today an attempt in such terms lacks relevance, largely because of the vagueness and indeterminateness of the end to be achieved. The concept of 'social unity' and the notion of 'living with one another' merit a great deal of analysis; like so many of the abstractions handled by educationists and indeed by social theorists in general, they rarely get it. Nor, alas, will they get it from me. I have only the space to note the part played by the democratic aspiration towards a 'common culture', more overtly manifest, perhaps, in America, where the Harvard *Report* is symptomatic, than in England. I can simply sum up by saying that I suspect, in general, the notion of social unity to be a will-o'-the-wisp. If nothing else, the failure to include the public schools makes nonsense of this particular pretension. In any case, social groupings of a sort are inevitable in any large-scale society of the complexity of our own; and it is absurd to think that all such groupings are likely to share compatible ends. We have probably gone as far as we can, in the Welfare State, to alleviate social tensions. The harmonious society is likely to remain a pipe-dream of humanity. What we *need* in the way of social harmony is an agreement not to cut each other's throats and not to use the police and the concentration camps as methods of political persuasion; for it is as well to remember that fullness of life arises out of conflict as well as out of harmony: that if we had no-one on whom to sharpen our wits, our minds would soon atrophy.

What I am concerned to point out, however, is the incompatibility between the desire (which lies behind the dissatisfaction with selection) to give all children the opportunity to become as highly educated as possible, which is likely to bring out the differences between them, and the aim of bringing them together in the new harmonious society. Indeed, Professor T. H. Marshall has pointed to the ambiguities inherent in the notion of equality of opportunity as enshrined in the 1944 Act:

> Its aim is to eliminate hereditary privilege. In essence it is the equal right to display and develop differences, or inequalities; the equal right to be recognised as unequal. In the early stages of the establishment of such a system the major effect is, of course, to reveal hidden equalities—to enable the poor boy to show that he is as good as the rich boy. But the final outcome is a structure of unequal status fairly apportioned to unequal abilities.

In the one case, a new social hierarchy based on different levels of technical accomplishment and administrative responsibilities seems to be implied; in the other the promotion, in some degree, of a 'new' egalitarian society, based on a common culture.

And, indeed, I think that experience will show that these are not compatible aims; and the uncertainties over streaming and the allocation of staff I have noted in some of the schools I have visited betrays some confusion in the mind of heads. Education of the sort that we formally impose is willy-nilly a divisive phenomenon unless the curriculum is so arranged that the brighter children are not academically pressed on, as seems to have happened in America. There, the social divisions, which persist, exist within the school in other terms. I don't quite know which way the cat will jump in this country, though I confess to feeling rather less anxious about the egalitarian implications of comprehensiveness than I did some time ago. Nevertheless, egalitarian notions—noticeably in the idea of 'parity of esteem' which was so

powerful immediately after 1944—have considerably affected the present situation. Moreover there are disquieting indications, in some of the published work on the comprehensive school, of a desire to obfuscate the issues by verbal juggling. Thus, in a recent compilation, *Inside the Comprehensive School*, a headmaster writes:

> We are learning that perhaps there are not such great differences in the quality of children's minds as in the nature of them, and that before we begin to adjust the content of their education in quality we must explore different ways of adjusting manner of presentation and time allocation.

I would ask you to note the incipient dishonesty of the contrast, in the context, of 'nature' and 'quality'. My guess, however, is that the pressure of public opinion, the need to sustain comparison with the grammar schools for a long time to come, the whole conception of education that so many people in this country hold as a means of getting on, the absence of some of the particular social problems, such as a polyglot population, which have shaped the American High School, mean that we shall probably escape at least some of the academically displeasing features of that institution. In any case, with the coming of the 'affluent society', general interest in the problem of equality has somewhat declined, as Professor Galbraith has pointed out.

So far I have tried to bring out how interest in secondary schooling has been influenced by *social* pressures and ideals, whether bureaucratic and technological ('social need') or egalitarian and 'democratic'. Relevant to both influences is the warning uttered by Mr. T. S. Eliot:

> Any educational system aiming at a complete adjustment between education and society will tend both to restrict education to what will lead to success in the world, and to restrict success in the world to those persons who have been good pupils of the system. The prospect of a society ruled and directed only by those who have passed certain examinations or satisfied tests devised by psychologists is not reassuring: while it might give scope to talents hitherto obscured, it would probably obscure others, and reduce to impotence some who should have rendered high service.
>
> (*Notes towards the Definition of Culture*, p. 101.)

I have several times during the course of this exposition put in admonitory phrases intended to hint a misgiving about the sort of values implicit in some of the propaganda for secondary re-organisation, and about the criteria of assessment used in judging the success or otherwise of the system. I must make it quite clear that I am very much in favour of bright children having their chance. Even when European society was at its most static and hierarchical, there were always agencies through which the clever could rise, and I welcome the proliferation of these agencies. Nevertheless, we must beware lest the struggle for status and the scholastic measures to which it leads should blind us to other functions of great educational importance but neglected because they do not immediately forward what seem to be the main aims of reorganisation.

For example, one desideratum of 'comprehensiveness' is the common curriculum, for at least two years—sometimes even an attempt at a common syllabus—so that all can at once start equal and share the same basic experiences. One danger of this remains, of course, the possible injury done to the bright child; he may be kept back so that the rest can keep up with him. Another, just as possible, is that the true potentialities of the less able child will be neglected in an educative attempt to keep up with the intellectual Joneses, so as not to fall behind in the social struggle. The notion of a common culture is inherently an absurd one, simply because many children are just not capable of understanding or appreciating much of the 'culture' produced by the educated classes and cannot be educated to do so.

Instead, then, of facing the fundamental problem: ' What ought we to teach the less bright child?', which, when all is said and done, the secondary modern school faced us with, we have sidestepped the issue by trying to pretend that all children are nearly the same, or ought to be nearly the same, even if they are palpably not—or different in 'nature' but not in 'quality', or whatever other formula can be found to disguise the realities of the situation. Had a satisfactory solution to the problem of the average and below average child been found there might have been much less interest in comprehensiveness. The Secondary Modern School has never been given a chance; for what is fifteen years in the life of an institution of such complexity?

Indeed, in none of the schemes of secondary reorganisation I have examined do I find any real

attempt to ask the fundamental questions raised by universal literacy, to assess the way our society is going or to question the values on which that 'progress', largely technical, is based; and this despite the fact that many of the greatest minds of our times have felt themselves profoundly out of step with the whole trend of our civilisation. I find a certain pretentiousness about what the school can do and sometimes an inflated sense of its importance in the social revolution of our times; I find an almost universal acceptance of the more superficial values of our society concerning what constitutes educational success. But I find little appreciation of the tremendous problems brought about by the death of the old folk culture, killed by industrialisation, and of the consequence that our people are spiritually and morally adrift in that candy-floss world of commercial values so ably analysed by Richard Hoggart in his book symptomatically entitled *The Uses of Literacy*. I see little sign in any of these schemes of any understanding of the problems which are likely to face us as we move into C. P. Snow's brave new world of 'electronics, atomic energy, automation', a world geared to what Lawrence called the 'plausible ethics of productivity'—except an interpretation of 'social needs' in largely those terms. To put it another way, our present trends in secondary schooling seem to involve largely an education for efficiency as that efficiency is understood in the affluent society, not a training for life as the great poets and artists and religious leaders have understood that word. I do not, of course, mean to suggest that 'poets and artists and religious leaders' have agreed on the nature of 'life', but simply that they have suggested a dimension to human existence beyond that of mere material advancement which, however welcome in some respects, seems to be too exclusively our preoccupation. Whether there is any close relationship between the demands made by industrialisation on the nature of people's work and the sort of cultural situation diagnosed by Hoggart in that book I cannot go into here; though a reading of Georges Friedmann's monumental *Industrial Society*, with its balanced but disturbing information concerning the decline in demand for skills brought about by industrial rationalisation, would suggest some close links. The evidence of Simone Weil in *The Need for Roots* is relevant here, too. Automation may necessitate a higher level of skill for more people; but it may also bring more leisure for the majority. The problem of more leisure, when one considers how it is spent by so many people at present, ought to be very much in the minds of our educationists; this, too, at a time when, in America, the four-day week has already been a Vice-Presidential talking-point and when Sir George Thomson, in *The Foreseeable Future*, can pose the question: 'What is the future of the stupid?'

Nor is this anything like the whole of the problem of what to teach. For the brighter children, for instance, there is that dichotomy symbolised by C. P. Snow's *Two Cultures*, the most recent of a stream of writings which during the nineteenth and twentieth centuries have asked questions about the fragmentation of our culture and have faced us with the challenge of the scientific revolution to the traditional curriculum; and here I think of science not only in terms of technological applications, but also in terms of thought, providing us with some picture of what is. At the same time, the claims of the new technological humanism to the virtues of which, in their various ways, Sir Eric Ashby and Georges Friedmann have drawn attention, need examination. When such profound issues are at stake, it is sad to see quite so much money and energy spent on the organisational aspects, and the philosophy of the matter concerned with such comparatively superficial social strivings as I have touched on in this paper. (Though seemingly so parochial, in reality the conflict over compulsory Latin at Oxford and Cambridge, because it faces us with the whole problem of content, raises issues inherently more profound and serious than the whole comprehensive movement.) It is perhaps partly because of an over-simplified conception of the power of organisations to affect our lives, that the organisational aspect has received the attention it has. The faith in organisations stems from a naive rationalism which needs to be corrected by a fuller comprehension of human complexity. I would not suggest that the organisational aspect is a matter of total indifference; it may, indeed, affect to some extent the quality of what goes on—radical changes, for instance, may possibly destroy what of good has only with difficulty been built up. But thinking at the administrative level involves

too high a degree of abstraction from the real business of education, which is finally a matter of what happens in the class-room.

The challenge of our times is 'what to teach'—particularly to the less able children, those who suffer the real deficiencies of the industrial age with its all-too-frequent degradation of personal skill and satisfying work, or its cultural impoverishment and its encouragement of a debilitating indulgence in an 'entertainment' of fantasy. The real question is, 'Can we in the schools do anything towards the evolving of a new folk-culture?' Can a syllabus in humanly satisfying terms be framed round the four great centres of the self-expressive, affective life, the domestic life, the physical life and the environmental challenge of science and the machine? Certainly there *has* been discussion on the content of education—but nothing really comparable in intensity to that, say, devoted to the difficulties of selection.

So far I have been animadverting on the climate of our times in relation to secondary reorganisation. I want to end on a more particular note. Whether the remarks I have made so far are acceptable or not, it is still true that we are faced with an evolving situation, the practicalities of which require comment.

My recommendations stem from what I have already said. My first plea would be for diversity of secondary school provision. If we are to tackle this problem of what to teach, related as it is to the *quality* of our living and hence to the cultural satisfactions of our people—which I have taken to be a central problem of our times, now that most of us have enough to eat, and a number of us a little left over for a washing machine—our thinking must not be seduced by these superficially attractive but basically spurious claims for social unity. Such a unity is unobtainable, anyhow, without the concentration camp; but the constant flaunting of the need can induce a dangerously nerveless state of 'organisationmanship'. Nor need our democratic susceptibilities be offended by what I have just said. There is an important strand of democratic theory which stresses such diversity and difference as I am today urging, rather than homogeneity and similarity, with their disturbingly totalitarian overtones. De Tocqueville noted the two tendencies of the democratic social process:

> the one leading the mind of every man to untried thoughts the other inclined to prohibit him from thinking at all . . . (when) the human mind would be closely fettered to the general will of the greatest number.

For all the talk about selection at 11+, it is perfectly possible at that age to make some quite radical divisions, provided machinery exists for correcting mistakes later, and provided we are not frightened to use it.

But this diversity, I think, should be manifest within a number of reasonably small separate establishments, each devoted to a fairly specific task in relation to a particular set of educational problems, rather than to an attempt to cover the whole intellectual range within one huge conglomeration. One thing that lovers of new systems will not appreciate is the danger that their innovations will pose as many new problems as they purport to solve in the way of old ones. We live in an imperfect world; and human experience goes to show that unless care is taken the solution of one problem easily leads to the proliferation of others. I see no signs that these comprehensive schemes solve more problems than they pose or even that they face the right issues. Moreover they can be too easily destructive. I intend a reference here, of course, to the grammar schools, one of the successes of our educational system. No-one in his senses would want to present the grammar schools as faultless—I don't, for instance, think they always do as well as they might by their less bright pupils. Nor do I think they provide sufficient opportunities for aesthetic education. But in an imperfect world they have maintained some corner of respect for the things of the mind. Their link with the universities ensures an attention, at a particular and appropriate level, to important academic disciplines. Furthermore, they have displayed a peculiar conscientiousness about their performance of their function which is ill-rewarded by the sort of remarks which our reformers sometimes cast at them: I refer to accusations of 'intellectual snobbery' and the like.

Another good reason for the small, manageable institution is the concentration of attention it permits on a specific set of educational problems, with the possibility of a specially trained staff for the children concerned. Too much diversity within a single environment necessitates too great

a dispersion of effort and of attention. Not all heads see even the fundamental problems of any particular intellectual level; to expect them to solve those associated with the whole range of ability is to anticipate a race of paragons which we have no right reasonably to hope for. And I do not believe that deputies can command the respect that a head can; a deputy, therefore, is likely to be at a disadvantage in any adjustments he may wish to make—a point made by a number of teachers who have actually taught in comprehensive schools.

My third principle would be that of continuity. There are, of course, arguments for a break at 13, 14 or 15 after one which takes place at 9 or at 11. I admit the force of some of these arguments, but I can only register my conclusion that I do not find them compelling. Provided adequate provision for transfer is made, the continuity of a five- or seven-year stretch of schooling is an advantage. It enables the subject teacher to plan the development of his discipline in some degree of perspective, thus affording him the opportunity of pursuing it with some relevance to its philosophic nature, rather than as something to be taken out of his hands, or given over to him, in chopped-up bits. There are, I think, other advantages in continuity, but this is certainly an important one.

My fourth consideration would be a concern, in any changes made, for 'piece-meal' rather than 'Utopian', planning, to employ Professor Popper's terminology. I must emphasise that rigid tri-partitism—or bi-partitism, as it is in many areas —is no longer defensible; but in the necessities of change I have been impressed by two important points. Changes which occur should take full account of what already is working successfully, as a matter of policy and as a matter of humanity; I don't like to see teachers used as pawns and their loyalties set at naught. Furthermore, all changes made in organisation and set-up should arise out of full consultation with teachers working within the current situation. Opposition to a new plan may be the result of inadequate information or even of pig-headedness; and an education committee in a hurry—and who isn't in a hurry these days to urge us to buy the next contraption—may be tempted to ride roughshod over exasperating susceptibilities which get in their way. But it is as well to realise that such concern on the part of teachers springs from a sense of loyalty and responsibility which is the most precious attribute of the teaching profession.

These, then, are some of my major principles; and I am the more encouraged in putting them forward in that I have found them to a considerable extent at work in some areas which I have recently visited. At Chesterfield and Southampton a scheme of biased courses is in operation which in effect treats the whole of the secondary education of the borough as a unit, providing a wide range of opportunity based partly on parental choice and partly on some degree of selection procedure. The academic schools are maintained—at Chesterfield they have lost their appellation of 'Grammar', and, indeed, in deference to parental wish may not always take the very brightest children, who may opt for another type of course. In order to get over the borderline difficulty, a number of the schools in Southampton as well as those primarily academic provide courses known as Grammar courses, leading specifically to General Certificate of Education; in Chesterfield most of the non-academic schools provide similar opportunities for General Certificate work. Each of the non-academic schools also provides a course biased in a particular direction to meet a wide variety of interests in addition to a general education in 'core' subjects. Thus in Southampton four-year courses are provided in Art and Craft, Craftsmanship, Farming and Gardening, and five-year courses in Commercial subjects, Seamanship, Secretarial and Technical subjects. Opportunities for domestic science, needlework, pre-nursing courses, and other wide possibilities of a technical nature appear in the Chesterfield scheme. In Southampton, a chance is given to enter for a wide variety of examinations; but, as at Chesterfield also, emphasis is placed on the non-vocational aspects of the courses. The aim is to utilise the children's interest in a particular bias in order to provide a sounder education, not to prepare them for a particular job.

It seems to me that what has occurred in these areas is an evolution, not a revolution; the existing system has been modified to meet valid criticism, but the network of medium-sized, independent schools has not been abandoned for large-scale comprehensives. The academic schools have not been destroyed but flourish. Any tensions resulting

from the introduction of the scheme have been completely resolved, largely as a result of the excellent relations existing between office and school. Again, the scheme seems to be satisfying the parents more and more. Every effort is made to meet parents' choices—public relations in both areas are admirable. Furthermore, the quite definite opinion, unequivocally expressed by every head I met without hesitation, is that the system as it works gives every child a chance to prove himself or herself and that the door of academic advancement is always wide open; and this the parents seem increasingly to realise.

All the secondary heads of the boroughs work together well and meet with reasonable frequency. The transfer scheme between schools depends on this co-operation and seems to be a very real and serious matter. The courses are varied and provide a wide choice of opportunity for the children of the town with their different interests. The attempt to use vocational biases in a non-vocational way seems to have been attended with a considerable measure of success. The schools with technical biases have excellent reputations in both areas. In both areas, too, there is an increasing tendency to stay on, especially to take Grammar courses. Thus, in Southampton the number of those taking Grammar courses in the secondary modern schools has trebled in ten years. In 1952 the wastage among those taking such Grammar courses was 50 per cent; by 1958 it had dropped to 30 per cent. Finally, one highly interesting feature of the Chesterfield scheme is that it has been approved of by both political parties.

There may be difficulties in extending such a scheme to areas above a certain size, because of the difficulty of access some children would have to the various schools. It may also be difficult to apply in rural areas, where the schools are very scattered. In such areas, small scale comprehensives may be necessary. Nor am I satisfied that either authority has thought out sufficiently the problem of content which I have spoken of above. In this, of course, they are no worse than any of the others.

In what I have said I have been rigidly selective. The whole business of reorganisation is a more complex matter than I have made it seem. But in the space available I have had to be highly selective; and I have tried to point to what I think are the vital issues.

BRITISH ASSOCIATION NEWS

CARDIFF MEETING

World Food and Population

The last few decades have seen immense advances in agricultural, biological and technological sciences. Man's capacity to produce food is greater than ever before.

But at the same time there has been an unparalleled upsurge of population, especially in the less-developed countries. Death rates have fallen sharply with, so far, no corresponding fall in birth rates.

Can food production be increased sufficiently rapidly to meet the ever-growing demand for more and better food? So far improved methods of agriculture have been effectively applied only in advanced countries.

The world food situation raises a bewildering series of questions:

How can the farmers of the less-developed countries be taught the newer methods of agriculture? How well are these methods adapted to tropical conditions? What are the significant gaps in our knowledge and what new research is needed? What changes should be made in the traditional patterns of land tenure, of farm credit, of marketing to create favourable economic and social conditions for agricultural development? Is the rapid development of food production likely to be in conflict with indigenous cultures? How can the standard of living be raised and what steps can be taken to provide general and technical education? How can the necessary industrial and technological expansion be financed? How can all this and more be done in time to avoid the potentially tragic consequences of a growth of population seriously outrunning food supplies?

Answers to these questions will not come easily but it is felt that by taking a fresh look at the whole problem it will at least be possible to indicate some of the steps which could be taken to improve the situation, and to increase public understanding of the issues involved.

For this reason one whole day (Monday, September 5) will be set aside during the Cardiff Meeting for a discussion of this main theme. In order that all members may attend there will be no Sectional sessions on that day.

Sir George Thomson, President of the Association, will take the Chair during the morning session at which the principal speakers will be Dr. N. C. Wright, C.B., Deputy Director-General of the Food and Agriculture Organisation in Rome, Prof. D. V. Glass, Professor of Sociology in the University of London, and Dr. W. A. Lewis, the Principal of The University College of the West Indies. Dr. Wright will consider the present supply of food and indicate existing trends; Prof. Glass will outline present trends in world population and Prof. Lewis will deal with economic aspects of the production and distribution of food.

The afternoon session will be introduced by Sir James Gray, Past President of the Association. Prof. L. Dudley Stamp, C.B.E., Professor Emeritus of Social Geography in the University of London will present a paper on land use and food production. He will be followed by Sir Alexander Fleck, K.B.E., F.R.S., Past President of the Association, who will consider industrial and technological needs. Dr. H. D. Kay, C.B.E., F.R.S., Professor Emeritus of the University of Reading, will then deal with the scientific aspects of food production. The final address will be given by Prof. P. M. S. Blackett, F.R.S., Professor of Physics, Imperial College of Science and Technology.

* * *

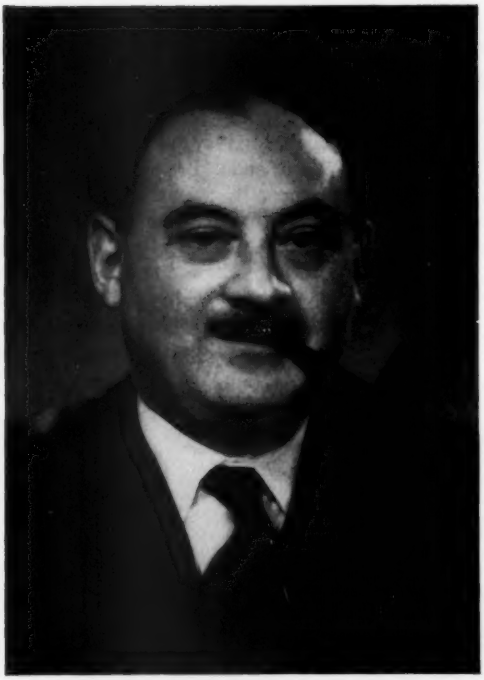
Young People's Programme

The seriousness with which the British Association takes its task of bringing science to the young needs no underlining today. Lectures to more than 32,000 schoolchildren in the past year, Junior B. A. Meetings during 1960 in Birmingham, Belfast and Sheffield—with audiences that add 8,000 to that figure—are witness of the need and of all that is being done to meet it; and the programme which is being planned for young people at Cardiff is as brilliant as any of these, with the added dimension that, as part of the great Annual Meeting, the young people will have the chance to dip here and there into the riches of the main programme.

The programme follows the pattern that has proved its worth at Glasgow and York. There will be an illustrated lecture on each of the afternoons of Thursday, Friday, Monday and Tuesday, September 1, 2, 5 and 6; and a 'Brains Trust' on the evening of September 1, at which a panel of scientists, under the chairmanship of Mr. Percy Cudlipp, editor of the *New Scientist*, will answer questions put to them by the audience (which it is hoped will include not only students but their parents and other interested adults). Once again

CARDIFF FROM THE AIR

The aerial view of the city above shows the layout of the Civic Centre buildings. On the left are the University College buildings in the foreground and the National Museum beyond; the central group is the Welsh Board of Health Offices and beyond Alexandra Gardens, the City Hall; on the right appear successively the Temple of Peace, the Welsh College of Advanced Technology, the Glamorgan County Hall and the Law Courts. Beyond and to the right of the Law Courts is the Castle Mound and Keep, and to the right again the Castle itself. Directly beyond the Castle, backed by a large block of buildings, is Cardiff Arms Park, home of Cardiff Rugby Club. Beyond again is the General Station. In the background are the Docks. *(By courtesy of H. Tempest (Cardiff) Ltd.)*



Professor A. Charlesby.

this year, there will be an invaluable display of the work being done by science classes in a wide range of local schools. Thirty schools are contributing, in fact, to a Science in Schools Exhibition, which is being arranged by an Advisory Committee of teachers from Cardiff, Newport and Monmouthshire. In the first of its two sections, pupils will demonstrate typical experiments in physics, chemistry and biology; the second section will include a display of results obtained in projects and surveys of local geographical, geological and biological interest carried out by groups of pupils.

The York Lecture, founded last year to honour the City that saw the Association's birth, will be inaugurated by Sir James Gray on September 1, with a talk on 'The flight of birds'. In this lecture, Sir James returns to the subject on which he is probably the world's leading authority and with which we must always associate his name. The aeronautical performance of a bird, he tells us, compares very favourably with that of a modern aeroplane or helicopter, and he suggests that man may do better when he learns to make aeroplanes with flexible instead of rigid wings.

Prof. Charlesby, Professor of Physics at the Royal Military College of Science, Shrivenham, has chosen as his title 'Atomic radiation and materials'. His talk will deal with the many different forms of atomic radiation, which vary according to type and energy and which interact very differently with materials through which they pass. He will touch, too, on some of their applications—one of the earliest of these was in the treatment of cancer. This practical approach will also be apparent in Prof. C. E. H. Bawn's lecture on 'Plastics and fibres', which deals with the particular kinds of chemical substances which can be synthesised into plastics, fibres or rubber. This can be a subject in which 'seeing is believing' and Professor Bawn will include demonstrations of the making of plastics and fibres and will carry out experiments to illustrate their properties and uses. The fourth lecture, by Mr. B. B. Lloyd, on 'Ends and means

Sir James Gray.

Professor C. E. H. Bawn.

in human respiration', completes a remarkably varied and well-rounded programme. The greatest investigator into the mechanisms relating input and output in breathing was John Scott Haldane and this lecture includes an account of recent work on human respiration done in Oxford, springing directly from the pioneer studies of Haldane. Mr. Lloyd is collaborating at the moment with Dr. Pugh on preliminary scientific work for Sir Edmund Hillary's ascent of Makalu, and this adventurous as well as practical aspect of his subject will add tremendously to the excitement of what he has to say.

* * *

INTER-MEETING ACTIVITIES

Junior B.A.

The Birmingham Junior British Association meeting, arranged by the West Midlands Area Committee and held at the University of Birmingham over four days from March 22-25, was attended by a total of 3,825 young people from all over the West Midlands. This was the second meeting of its kind (the first venture was at Nottingham in July 1959) and incorporated a number of changes based on lessons learnt.

Each of the young people heard two lectures during the day, one on the subject of his choice and the second on something quite different—lectures being arranged under five main headings (Physics, Chemistry, Biology, Applied Science, and General Subjects). Each person also saw a balanced programme of outstanding scientific films lasting an hour. In addition there were a number of exhibits in the Great Hall of the University provided by departments of the University, the Science Museum, and industrial firms.

On the first day there was a short opening ceremony, at which the Lord Mayor (Alderman John Lewis) welcomed the efforts of the B.A. and the Area Committee, and the young people to Birmingham and to the University. Sir George Thomson took the chair, and the Vice-Chancellor, Dr. R. S. Aitken, thanked the Lord Mayor.

B. B. Lloyd.

All the lectures followed the normal pattern for such audiences of being designed to broaden mental horizons—right away from the school science syllabus (and therefore informative for the science sixth) and yet sufficiently general to appeal to the arts sixth. Analysis of those attending shows that 62 per cent were boys and 38 per cent girls; of the boys, 60 per cent were science sixth, 21 per cent arts sixth, and 19 per cent 'others'; of the girls 46 per cent were science sixth, 26 per cent arts sixth, and 28 per cent 'others'. By general consent, the lectures achieved a remarkably high standard of presentation, as well as a good spread of interest and balance between subjects. The National Press showed a good deal of interest, and in spite of the nature of the lectures four of them were found to contain material for quite extensive news reports.

The weather was benign, so that the extremely careful preparations made by the University for all emergencies were hardly tested. The administrative arrangements were most efficient and there was hardly a hitch in the four days. This was due to the kindness of the University and the co-operation with the Area Committee. Not only do the Area Committee feel able, with equanimity, to contemplate making this Birmingham meeting an annual event, but the idea has been welcomed by the Education Authorities and the schools.

* * *

Glasgow Area Committee

The Glasgow Area Committee, formed for the purposes of the Young People's Programme, launched its campaign by taking a stand at the Fifth Scottish Schoolboys' and Schoolgirls' Exhibition at Kelvin Hall from March 22 to April 3. Science had not previously been represented at this exhibition, and running a stand at a public exhibition is a new venture for the B.A. The main attraction at the stand was Messrs. Ericsson's Telephones Ltd.'s electronic game 'Daedalus', very kindly made available and sent up from Nottingham with an engineer to ensure that the machine went on winning. Other exhibits were provided by local industrial firms and by the Royal College of Science and Technology, and 15,000 leaflets describing the purposes of the Young People's Programme, and of the Area Committee, were distributed to visitors to the stand. The Exhibition was attended in all by some 100,000 people, of whom 40,000 were parents.

* * *

Lectures

Continuing the development of lectures for Training Colleges, a series of five weekly lectures was arranged for Hereford Training College from February 19 to March 18. The speakers were Prof. D. L. Linton on 'Word Population and Food Supplies', Dr. R. S. McDonagh on 'Radioastronomy', Prof. L. S. Palmer on 'Dating Early Man', Dr. J. Fremlin on 'Power, Hope and Energy', and Dr. W. E. Swinton on 'The Significance of Modern Scientific Research and its Impact on Society'. The audience in each case was some 80 second-year students, who were asked afterwards to write essays on what they had learned from the lectures in relation to their future careers. This series also may become an annual event.

RECENT TECHNICAL ADVANCES IN CELL CULTURE

By Dr. J. PAUL *Department of Biochemistry, The University of Glasgow*

Tissue culture means growing animal tissues outside the animal in vessels such as test-tubes and bottles. These animal tissues include human tissues both of normal origin and from cancer material.

Tissue culture can be traced back to some experiments done by the embryologist Wilhelm Roux in 1885 although the credit for performing the first real tissue culture experiments is usually given to the American embryologist Ross Harrison. The method he introduced in 1907 became accepted as a standard technique. Essentially it consists of embedding a tiny fragment of tissue in plasma clotted by the addition of chick embryo extract. The technique is illustrated in Fig. 1. First of all, the tissue is placed in a small drop of plasma on a cover slip. A drop of embryo extract is added to this and just before it clots the two are mixed and the fragment is placed in position. A depression slide is then taken and a drop of vaseline is placed at two opposite corners. With this slide the coverslip is then picked up in such a way that the plasma clot containing the fragment of tissue is suspended over the well in the depression slide. The coverslip is then sealed to the depression slide by painting the edges with hot wax. When a culture of this sort is incubated for a few days cells begin to grow out from the original piece of tissue. They may multiply and migrate rather quickly and in a matter of a day or two there is usually a beautiful display of some of the cells of the tissue. This technique has been in use for over fifty years and is still used. However, it is very limited in many ways. In particular, only a very small amount of tissue may be used in any single experiment and it is very difficult to measure its metabolic behaviour in a quantitative fashion. Thus, it has been used mainly to make morphological observations. Although many experiments were done in the early days using this technique to tackle problems of metabolism and to make other quantitative investigations it was really incapable of being used for these purposes and most of these attempts proved futile and frustrating. However, in the past ten years or so a number of very important advances have been made which have opened up great new possibilities.

These advances have led to the development of a new kind of tissue culture which is coming to be called cell culture. The essential feature of this kind of tissue culture is that instead of growing a small intact piece of tissue dissected out of the animal the tissue is now completely broken up, usually by treating it with a digestive enzyme. The digestive enzyme which is most often used for this purpose is trypsin which is produced by the pancreas and normally breaks down proteins in the gut. When many tissues are treated with a $\frac{1}{2}$ per cent solution of trypsin at a pH of about 7·6, they are disrupted so that individual cells are released. Now it might be imagined that this treatment would digest the cells also and that they would be destroyed. However, the cell membrane appears to escape attack by trypsin and consequently the cells which are released from the tissue are found to be quite capable of continuing to live and multiply when placed in a suitable medium. This technique was first developed for use in certain embryological experiments but it is now very widely employed for the production of cell cultures for virus work. One of its most widespread applications, for instance, is in the preparation of monkey kidney cultures for the growth of poliomyelitis virus used in the preparation of polio vaccine. The technique is illustrated in Fig. 2.

A kidney is first obtained from a monkey and chopped up into very small pieces. It is then treated with a dilute solution of trypsin. Generally, this is done by covering the small fragments of tissue with a large volume of dilute trypsin solution in a salt

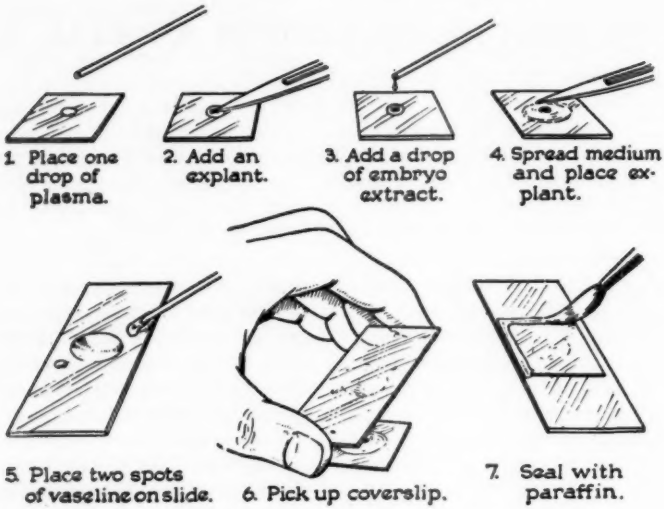

1. Place one drop of plasma.
2. Add an explant.
3. Add a drop of embryo extract.
4. Spread medium and place explant.
5. Place two spots of vaseline on slide.
6. Pick up coverslip.
7. Seal with paraffin.

Fig. 1.—Preparing coverslip cultures.

solution, the whole being stirred fairly vigorously for a prolonged period of time. Periodically the supernatant suspension of cells is decanted off. This suspension can then be placed in a tube and the cells separated from the trypsin solution by centrifugation. The next stage is to suspend the cells again in a fresh growth-promoting medium and to use this suspension to inoculate a large number of culture flasks. The entire procedure is very often carried out by semi-automatic means.

Now, even before this technique was developed it had been demonstrated by Carrel and his successors that certain cells could be maintained in a state of active proliferation for many years on end, in fact, for such a long time that there seemed no doubt whatsoever that given suitable conditions they could grow for ever. By this means, cell strains were developed. Nowadays there are many hundreds of these available.

Another big advance which was made not very long ago was the abolition of the plasma clot and embryo extract used in the traditional technique. The disadvantage of the plasma clot was obvious. It provided a solid, jelly-like embedding substance which was difficult to manipulate. Also, the difficulties of collecting plasma and preparing embryo extract were considerable and the manipulations involved in the technique were so tedious that contamination with bacteria frequently occurred and ruined the experiments. In the late 1940's it was found that in a large number of cases it was possible to dispense with the plasma clot entirely and that the cells would grow quite happily on the bottom of a glass flask. This observation removed one of the big difficulties in investigating the nutritional requirements of cultured cells because when such a complex material as plasma was present it was almost futile to try to define with any precision the components present in the cell's environment. However, it now became possible to proceed with this type of investigation and it was soon found that fairly simple mixtures of chemicals, such as amino acids, vitamins, sugars and salts would maintain the growth of the cells indefinitely. When these hurdles had been passed people immediately began to wonder about growing pure strains of cells, that is strains derived originally from single cells. The first achievement of this aim was accomplished by Dr. Katherine Sanford at the National Cancer Institute in the United States in the year 1948. She isolated a single cell from a mouse in a small piece of glass capillary tubing and managed to grow a culture from it. Her technique was first to prepare a suspension of cells and then to suck this suspension

up into a series of thin capillaries. Subsequently, she examined each capillary under a microscope until she found an isolated cell. She then broke the capillary on either side of this and embedded it in a plasma clot. Soon the cell divided to form two, the two became four and so on till a large culture was formed. This original technique was extremely tedious and although occasional successes were achieved, on the whole most people were discouraged from using it. A much easier technique was developed quite recently by some other workers who simply prepared a very thin suspension of cells and inoculated this into suitable vessels in a rich medium. When this was done it was found that colonies would grow from single cells. These could then be removed to other vessels and grown up into large cultures. This technique was particularly useful for determining the proportion of cells which was capable of growing into colonies and, in fact, became used as a measure of the ability of cell cultures to survive in certain given conditions. The main difficulty in this method is ensuring that the suspension consists of single cells and not clumps of two or three. There always remained the objection that perhaps not all the cells in the suspension were single. Perhaps some occurred as pairs or even as groups of three or four or more and thus the cultures might not be pure. To answer this objection in cases where it was of some importance, some other workers recently developed a simple technique of isolating cells by means of a micro-pipette and transferring them to small drops of culture medium where they were allowed to grow into colonies. By means of all these techniques it has become possible to grow pure strains of animal cells from single cells, to grow them in large numbers

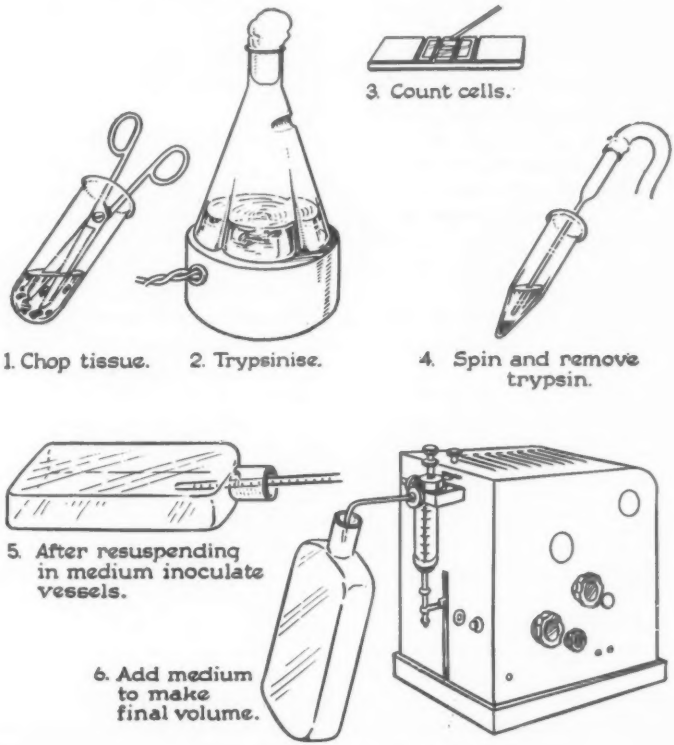

3. Count cells.
1. Chop tissue.
2. Trypsinise.
4. Spin and remove trypsin.
5. After resuspending in medium inoculate vessels.
6. Add medium to make final volume.

Fig. 2.—Trypsinisation of fresh tissue.

indefinitely and to grow them in accurately defined media.

For many purposes, particularly for biochemical work, it would also be desirable if they could be grown in suspensions in fluid media in the same way as yeasts and bacteria can be maintained. This has now been accomplished by employing methods which prevent the cells from settling down. These methods consist essentially of stirring the solution very vigorously so that the cells cannot adhere to the glass. Some cells grow particularly easily in this way. In other cases, it is technically much more difficult.

By means of the techniques of growing cells in suspension and the other techniques of obtaining them in suspension by treatment with trypsin it has become possible to grow cells in a manner which enables us to do quantitative experiments. For instance, it has become easy to inoculate exactly the same number of cells (as a measured volume of a suspension) into a large number of culture flasks so that one can start an experiment with exactly replicate cultures. Such experiments as this have proved particularly valuable in certain kinds of work, for instance in measuring the exact dosage of irradiation which produces radiation damage or in measuring the amount of a disease virus which produces a given amount of damage in a cell culture. Already some dramatic advances have been made in our knowledge of the behaviour of cells by means of these techniques. As I have pointed out, however, they are of very recent development, the oldest of them being about twelve years old and the youngest less than a couple of years. Thus we can expect that within the next few years we may see some very exciting advances in our knowledge of the behaviour of cells. It is particularly our hope that some of these advances may throw light on some of the most puzzling of human diseases and in particular perhaps the problem of cancer.

Acknowledgements

The illustrations, which are from *Cell and Tissue Culture* by Paul, are reproduced by kind permission of the publishers, E. & S. Livingstone Ltd., of London and Edinburgh.

MICROSEISMS AND STORMS

By Dr. J. DARBYSHIRE *National Institute of Oceanography*

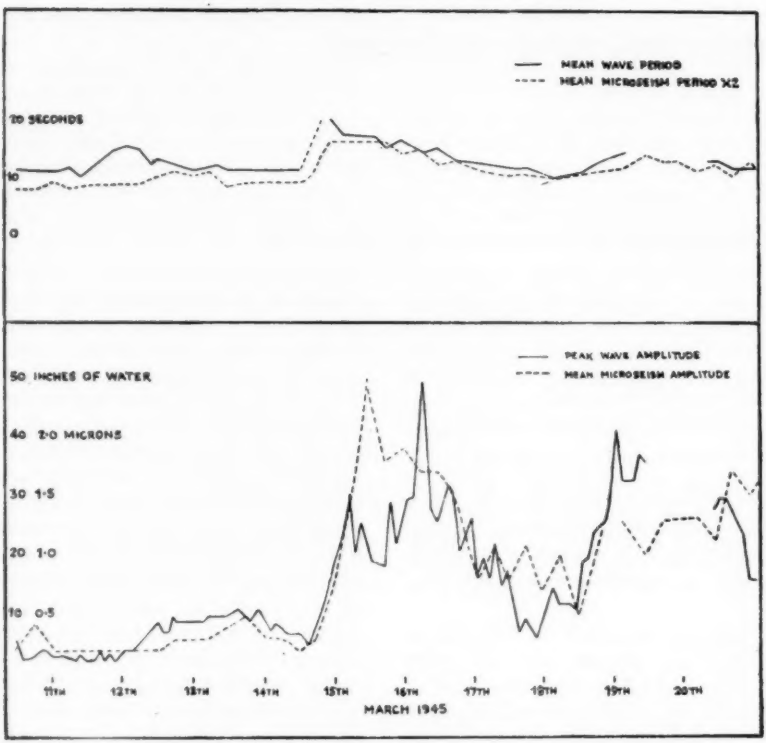
An earthquake is a well-known phenomenon but much less is generally known about the smaller tremors recorded on seismographs almost continuously. The most important of these are of frequency 0·1 to 0·5 c.p.s. and of amplitude up to 10 μ. These are usually called microseisms. There has been a great deal of conjecture in the past about the cause of microseisms although it soon became apparent that they were caused in some way by meteorological factors. Some thought they were due to barometric fluctuations and others thought they were due to the breaking of waves on rocky shores.

This last suggestion was made by Wiechert in 1905 and gained the support of many other workers, notably Gutenberg and Gherzi. The Indian scientist Banerji in 1930 noticed, however, that though microseisms were associated with monsoon activity in the Indian seas, they were always recorded before the swell arrived at the coast. This led him to believe that they were caused not by coastal waves but by waves in the open sea, although he was not able to put forward a satisfactory mechanism for the energy transfer from sea waves to ground waves in deep ocean. This presented a considerable difficulty as the effect of sea waves is not usually felt at large depths; it is well known, for instance, that a submarine deep down is unaffected by surface waves. There is a problem even in shallow water, for the microseism wavelength is much greater than the sea wavelength and the variations in pressure caused by a number of sea waves tend to cancel out over this distance.

This theoretical difficulty was not resolved for several years but in 1948, Longuet-Higgins found an explanation. It had previously been shown by Miche in France that if there were stationary or standing waves on the sea surface, then their effect does not disappear at large depths like that of ordinary progressive waves. A stationary or standing wave is formed when two progressive waves of equal height and length meet head-on. Longuet-Higgins showed that there is a finite pressure effect at the sea bottom also in the more general case when two waves of equal length but unequal height meet head-on, the pressure effect being proportional to the product of the amplitudes. This result can be proved from simple geometrical considerations which show that the centre of gravity of the whole volume of water is lifted up twice per wave cycle. This leads to a variation of pressure on the sea-bottom of twice the original sea-wave frequency, and the effect of the sea waves becomes cumulative over the microseism wavelength. The more elementary theory applies when the depth is not too large so that the pressure disturbance, which is transmitted with the velocity of sound, reaches the sea bottom and comes back in a very short time compared with the wave period. In very deep water, this is not the case and so the compressibility of water has to be taken into account. There is then no uniform unattenuated pressure fluctuation at large depths but a compression wave whose planes of equal phase are horizontal.

In nature, trains of waves of equal period (or length) can meet head-on when waves get reflected off the coast and meet the incident waves. Also in the case of a fast-moving depression which can often give rise in certain areas to trains of waves moving in opposite directions. Using values of wave heights and spectra usually found in the middle of storms and estimates of the amount of wave energy reflected off the coast, Longuet-Higgins found quantitative agreement between his theory and observations.

The theory requires that the microseism period



COMPARISON OF THE AMPLITUDES AND PERIODS OF THE PRESSURE VARIATIONS BELOW WAVES AT PERRANPORTH WITH THE AMPLITUDES AND PERIODS OF MICROSEISMS RECORDED AT KEW

Fig. 1.—Comparison of sea-waves at Perranporth and microseisms at Kew (after Deacon).

should be about half the sea-wave period, and for coastal waves, the microseism and sea-wave amplitudes should be proportional. A two to one relationship between the periods of the two types of waves had been found by Bernard in 1941. Deacon in 1947 compared waves off the coast of Cornwall and microseisms recorded at Kew Observatory and showed that in cases where reflection off the coast was predominant, there was a close relation between the amplitude of the sea-waves and microseisms and between the sea-wave period and half the microseism period. See Fig. 1.

I also carried out some work in 1950 which confirmed this theory. Sea-waves and microseisms are not simple waves of constant wave-period but cover a range or spectrum of periods. I obtained the spectra of the waves at Cornwall shown by Deacon and those of the corresponding Kew microseisms, for March 1945. These are shown in Fig. 2. The wave spectra show a new band of swell of over 20 secs. period arriving at 14.3.45 1500 and from this time onwards there is a very close correspondence between the two sets of spectra, with the microseisms having half the sea-wave period. There is a new band of activity in the microseism spectra, however, at 13.3.45 2300, 16 hours before the appearance of the new band on the wave spectra. Similar results were obtained for two other occasions when there was just one solitary storm acting in the Atlantic, and the microseisms appeared in one of these cases 28 hours before the swell. An investigation of synoptic

charts showed that in each case, the new band of microseisms appeared on the spectrum when the conditions were such that over a large area the winds had veered round sharply as required by the theory.

The work showed, as Banerji had found, that the microseisms preceded the swell and they should thus prove useful as storm warnings. As the wave-period in the storm can also be found, the wind speed in the storm can be estimated as it is related to the wave-period.

Work has also been carried on in estimating the direction of arrival of the microseisms to find the bearing of the storm producing them. The simplest method is the tri-partite method. In this a set of three seismographs are set at the corners of a triangle and the direction found by comparing the time of arrival of an individual wave which could be identified at the three points. This assumes that the waves are all of the same type and moving with the same velocity so that there is no change in the shape and form of the waves over the distance concerned. This, however, is not so and Shaw (1922) showed that when the distance exceeds 10 miles, there is no apparent similarity between the seismograph traces. An ambitious programme of direction-finding was laid on in the United States during the war based on this

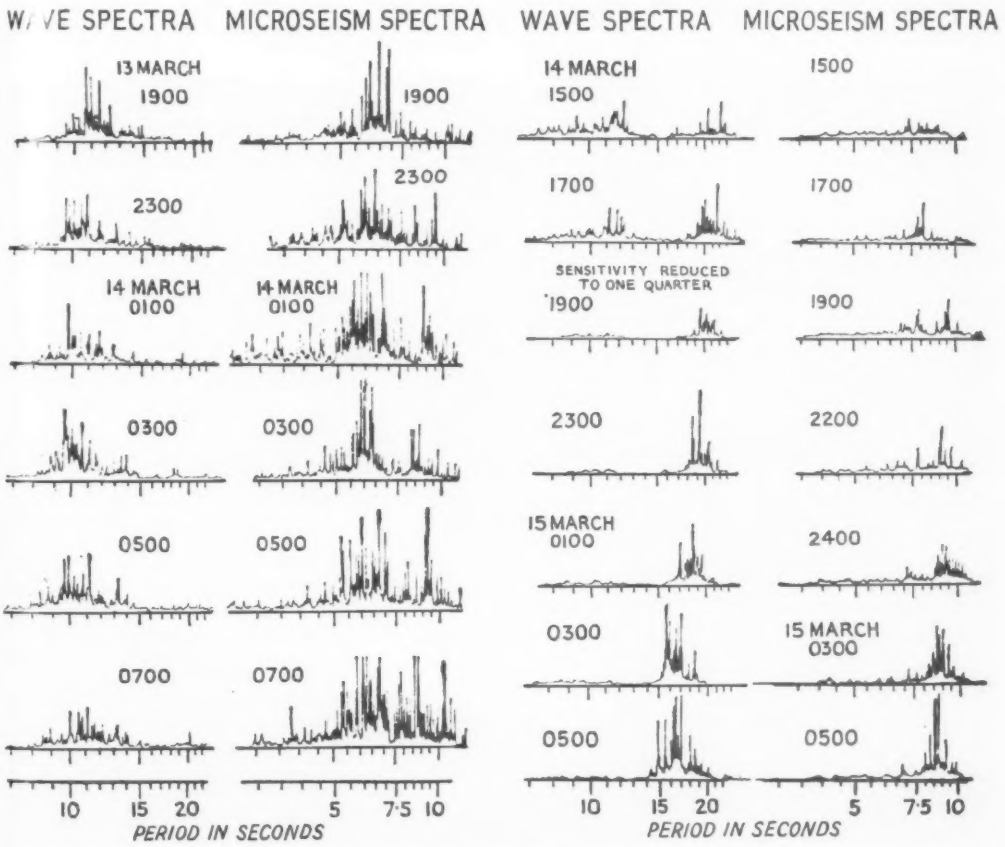


Fig. 2.—Comparison of the spectra of sea-waves and microseisms.

principle. The distance between the seismographs was usually 600 metres. This required very accurate synchronizing of the seismographs as time differences of the order of $\frac{1}{8}$ sec. would have to be measured. This method was not generally successful and was abandoned after it had been tried for eight years.

Another method of finding the storm direction is to consider the actual nature of the microseismic waves. In a semi-infinite homogeneous solid with a free surface, it was shown by Lord Rayleigh that a certain type of surface wave was possible. These waves are called Rayleigh waves and the motion is such that the ground particles move in ellipses, the motion being anti-clockwise when the waves move from left to right, the plane of the ellipse containing the direction of propagation and the vertical. If microseisms were waves of this sort, and they were recorded by seismographs which recorded the vertical, north–south, and east–west displacements separately, some very simple relations would be obtained. The tangent of the angle of bearing of the storm would be given by the ratio of the amplitude of the N–S displacement to that of the E–W displacement in the case of regular waves and by the ratio of the corresponding root mean square displacement for the general case. Also there would be definite phase differences between the three components which vary with the quadrant the storm is in. Dr. A. W. Lee (1935), obtained a statistical distribution of the phase differences in various cases when the

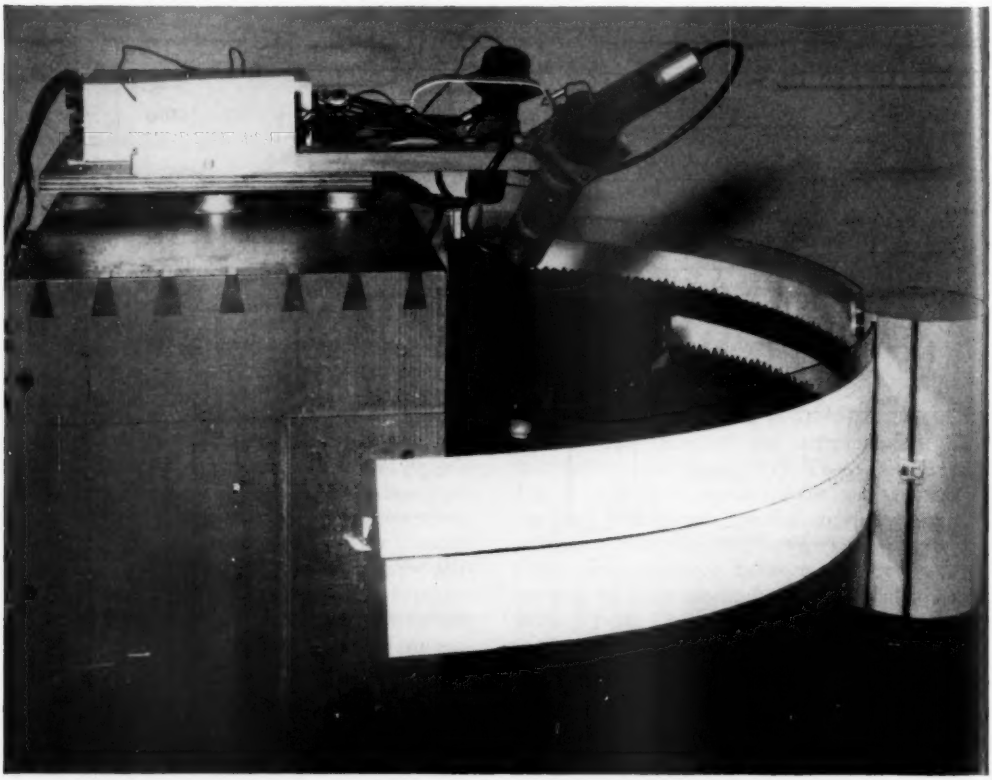


Fig. 3.—Analogue correlation computer.

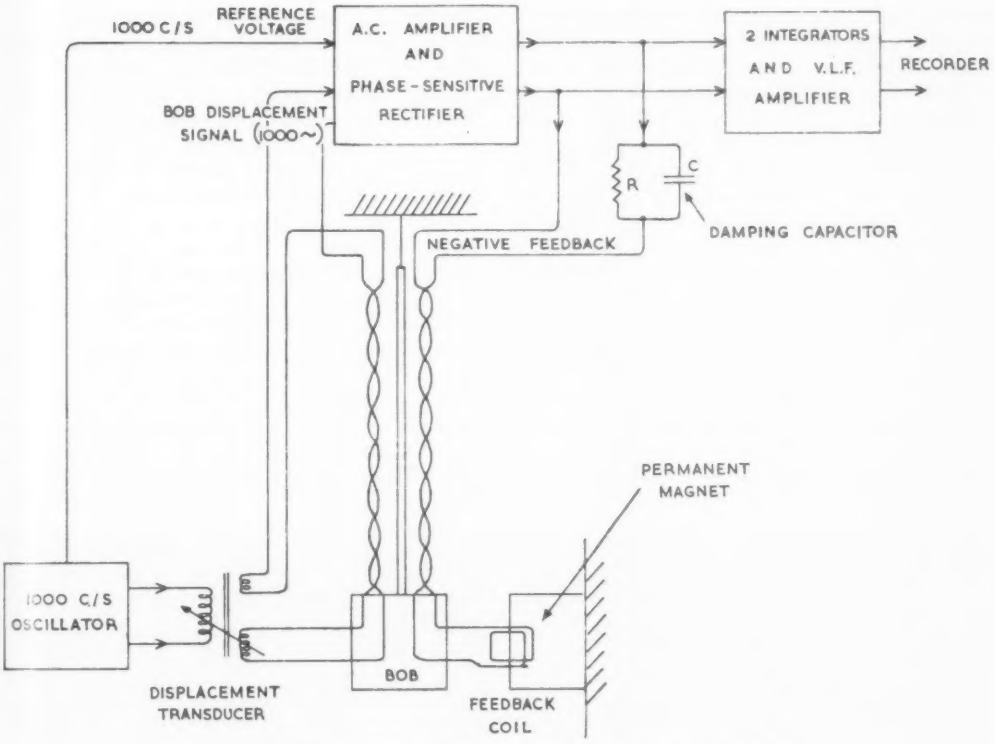


Fig. 4.—Schematic diagram of electronic seismograph system (after Tucker).

microseisms could be attributed to a definite storm and he found the distribution was consistent with the microseisms being Rayleigh waves.

I followed up this work in 1954 but found that I could not estimate storm bearings by assuming that the microseisms were purely Rayleigh waves. If a semi-infinite homogeneous solid has a thin layer of another medium on top of it, then Love showed that another type of surface wave is possible—Love wave motion. Here there is no vertical movement, and the particles vibrate at right angles to the direction of propagation. Under these conditions, Rayleigh waves are still possible, but now the velocity depends on the period as well as the properties of the two media. I assumed that microseisms consisted of both types of waves. The direction of approach can then be found by correlating the three components. The vertical component contains only Rayleigh waves and the correlation coefficient of the N–S component with it would give a measure of the amount of Rayleigh wave activity in the N–S component, and similarly with the E–W. Because of the phase differences and different instrumental characteristics, the correlation coefficient obtained from simultaneous readings from two records is not the maximum possible and one record must be shifted with respect to the other to obtain the maximum. The lag or advance of this gives the phase difference by taking its ratio to the mean period. Accordingly, if θ is the bearing angle.

$$\tan \theta = \bar{x} \cdot r_{xz} / \bar{y} \cdot r_{yz}$$

where $\bar{x}$ is the r.m.s. value of the E–W component and r_{xz} the correlation coefficient between this and

the vertical. The denominator contains the corresponding quantities for the N–S component.

It is not very easy to carry out these correlations. One could, of course, take digital values from seismograph records (which would have to be suitably enlarged) over small regular intervals of time and then work out the correlations by digital computer. The method I used was to employ an analogue computer. This has been described by M. J. Tucker (1952), see Fig. 3. The two records to be correlated are reproduced in a black-and-white silhouette form and placed one above the other along the circumference of a perspex semi-cylinder. Two strips of light scan both records at speed, one for each record, the horizontal distance between the slits being adjustable. The whole arrangement is viewed by three photo-cells so that the variations on the records are converted into an electrical output. This is squared and integrated. The final result gives the correlation and this varies as the strip distance is varied. The maximum value is taken and the phase difference can be estimated from the distance between the strips. I tracked one storm in 1951 successfully by this method.

This analogue computer was improved by Dr. H. M. Iyer, an Indian scientist, working at the National Institute of Oceanography. He incorporated band-pass filters in it so that waves of period 5–6 secs., 6–7 secs., etc., would be correlated separately without regard to the rest of the wave activity present. This refinement was very useful when there was more than one source of microseisms as the effects could be separated if they produced waves with different period ranges. Iyer also modified my original assumption that the Rayleigh and Love waves come from the same direction and he concluded that the Love waves came more or less equally in all directions, because

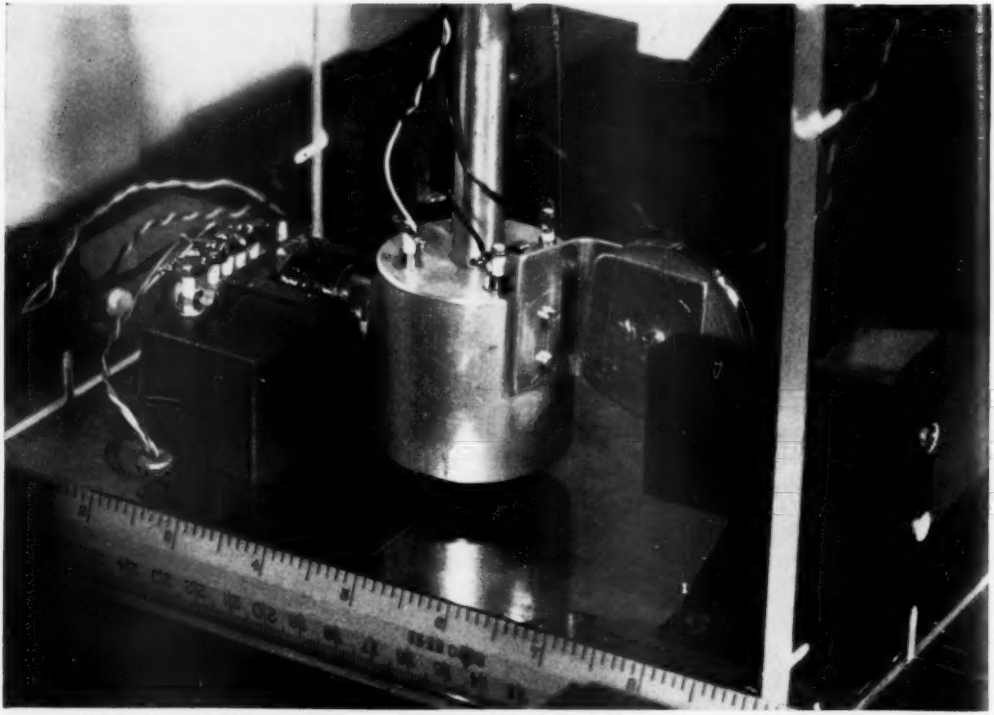


Fig. 5.—Horizontal seismograph.

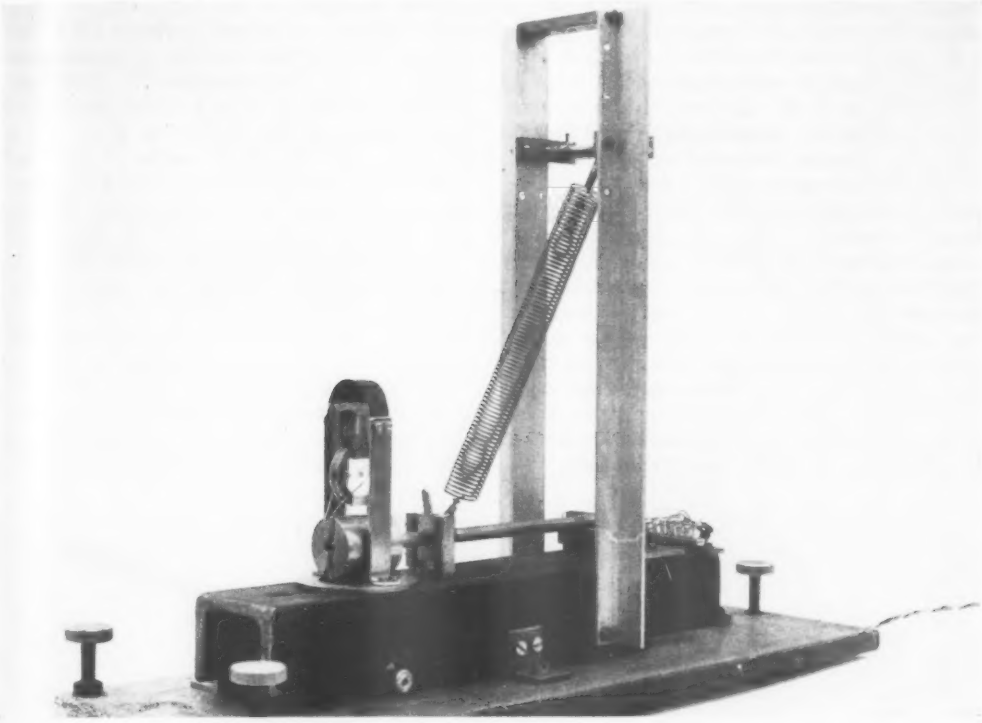


Fig. 6.—Vertical seismograph.

he obtained better results in storm tracking with this assumption.

In estimating the storm direction, some allowance has to be made for the refraction of microseisms. The Rayleigh waves are assumed to be formed between the sea-bed and the sea surface in the manner described by Stoneley (1926) and so their velocity depends on the depth of water, being greater the shallower the depth. The velocity also depends on the wave period. The effect of refraction is very interesting and there are often focusing and diverging effects due to bottom topography. Variations in direction up to about 30° can be caused by refraction.

The tracking of storms by these techniques always showed a direction which corresponded to a past position of the storm centre and was consistent with what would be expected if the microseisms were caused by the interference of waves meeting head-on.

Analysis of these seismograph records is still a laborious business and it is much better to be able to analyze and correlate the microseisms as they are recorded. This is not possible with the older type seismographs as there is very little or no electrical output. This has led to the designing of a new type of electronic seismograph by M. J. Tucker (1958). This has a magnification of 18,000 and a reasonably flat response from 1 to 10 sec. period. A schematic diagram of the instrument and circuit is shown in Fig. 4. Briefly it consists of a pendulum of 1·6 sec. natural period, the displacement of the bob (Fig. 5) relative to its mean position is measured by a transducer which gives a 1,000 c.p.s. signal balanced to zero output in the mean position. This signal is amplified and

rectified, taking account of phase, giving a voltage proportional to the bob displacement. This voltage is fed back to a coil attached to the bob and with one of its sides in the field of a permanent magnet, the sense is such that the force on this coil reduces the deflection. By arranging suitable circuits in this feed-back part, the period and characteristics of the pendulum can be varied at will. The seismograph is mechanically robust and easy to calibrate. With this instrument, the horizontal displacement is measured and in the properly engineered model, both E–W and N–S components are measured by the same instrument. A seismograph measuring the vertical movement is shown in Fig. 6 and works on a similar principle only now the pendulum is arrested in a horizontal position by a 'zero length' spring and the displacement is measured as before. These instruments are housed in a brick-lined pit in the Institute grounds.

These instruments are used with a simple device which automatically measures r.m.s. amplitudes, mean period, and the correlation coefficient between two components. This instrument is shown in Fig. 7. It is a robust moving-coil meter movement provided with a system of platinized contracts, which consist of studs and strips. The scheme is explained in Fig. 8. The studs are used for measuring root mean square displacement by connecting each one to a separate counter and summing up the number of counts. The period is determined from the strips which only cover half the range of movement of the needle. Thus a circuit is made or broken every time the needle passes through the zero position and the count of breaks in a minute gives the mean period. The correlation coefficient is obtained by using two of these movements, one for each component and using the long strip which is split at the middle,

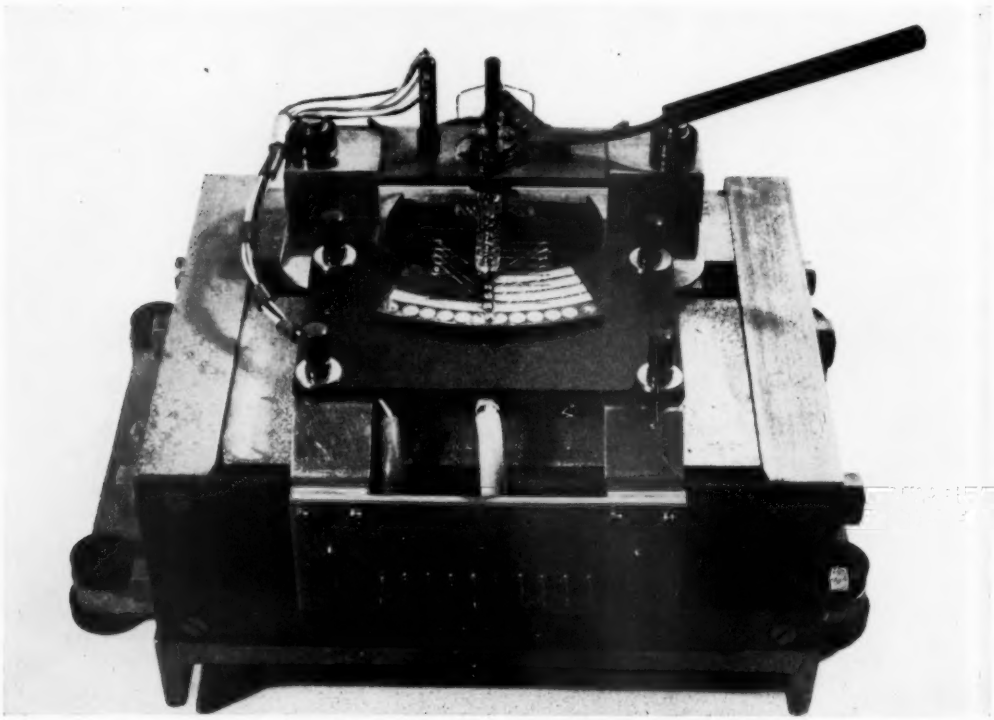


Fig. 7.—Simple correlation, amplitude, and period meter.

AUTOMATIC ANALYSER
FOR MICROSEISMS

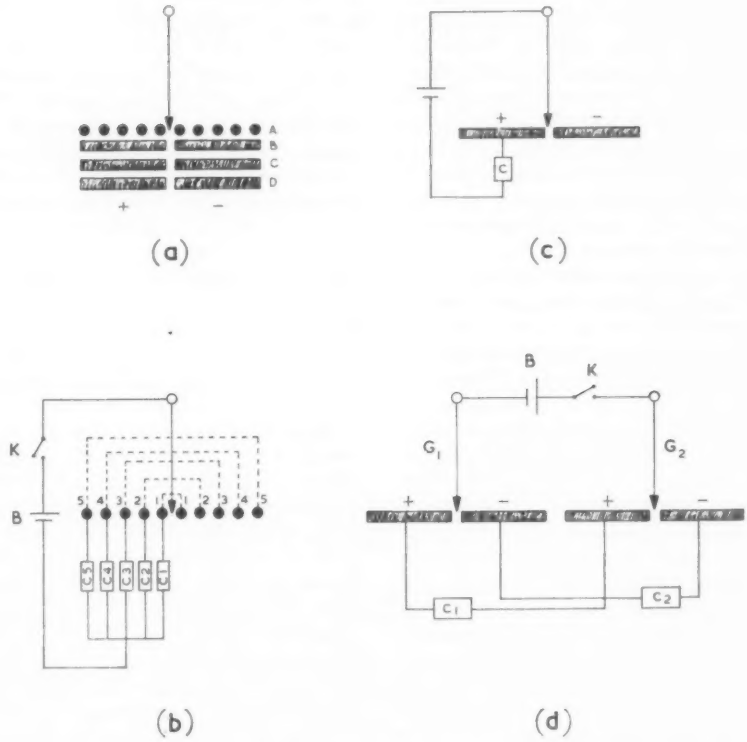


Fig. 8.—Schematic diagram of correlation, amplitude, and period meter.

so that when both needles are on the same side of the zero position, a circuit is made and it is broken when they are on different sides. The correlation coefficient can be determined by a simple formula derived by the Japanese scientist Tomado:

$$r = \sin(\pi/2)\,(n_+ - n_-)/(n_+ + n_-)$$

where n_+ is the count for needles on the same side and n_- that for needles on opposite sides. Band-pass filters can be incorporated in these instruments to confine the correlation within a narrow period range. Phase shifting circuits can be introduced to advance or retard one component with respect to the other.

The seismographs and correlation meters are portable and it is proposed soon to set up mobile stations and combine the tri-partite principle with the correlation technique. With this method there is no need to identify individual waves and the length of the side of the triangle can be increased up to 100 miles.

GENETICS AND ORIGIN OF SPECIES

By Dr. C. D. PIGOTT *Department of Botany, The University of Sheffield*

The year 1959 was the centenary of the publication of *On the Origin of Species* in which Charles Darwin set out and discussed in more detail the theory he had propounded in the celebrated Darwin-Wallace lecture of 1858. After the lapse of a century, it is clear that the publication of this work was the beginning of a revolution in biological thought. Darwin based his belief that species were not separately created but had evolved under natural selection, on inferences from an enormous number of observations, but, in his assertion that the present diversity of living organisms had arisen by processes still operating at the present time, he emphasised that these processes were accessible to experimental study. Darwin himself, therefore, laid the foundations for the experimental elucidation of the mechanism of the processes he had envisaged by his recognition of the dynamic nature of species, their liability to vary and for variations to be subject to natural selection.

Thus the mechanism of evolution has come to be regarded as having two components amenable to study. On the one hand is the individual organism's possession of an internal mechanism of inheritance and variation, whose study belongs to genetics and biochemistry, while on the other is the quantitative and qualitative adjustment brought about in the structure of populations by the action of the environment, whose study belongs to ecology and experimental taxonomy.

Since the beginning of this century, the physical basis of transmission of hereditary characteristics had been clearly demonstrated to be largely through inherited particulate determinants, or genes, which are passed from parents to their offspring. From studying segregation of visible or experimentally recognisable characters and combining this with knowledge of the behaviour of chromosomes during cell division, gamete formation and fertilisation, it is clear that most genes are located in the chromosomes. At meiosis the pairing of the two sets of chromosomes, which were derived originally from two parental gametes, is accompanied by crossing-over of the chromosome threads and the exchange of lengths of material. The separated threads pass to the gametes and in outbreeding organisms where the two original chromosome sets were similar but not identical, the fusion of gametes brings together two sets of reconstituted chromosomes. During this process groups of genes will become separated from their original neighbouring groups and joined at the equivalent position on the chromosome to new ones. From measuring the frequency of crossing-over between gene-positions (loci) by observing the frequency of recombination of visible characters, the relative distance between loci can be established.

Biochemical and genetical studies have provided evidence that genes must be regarded as biochemical organisers which under certain circumstances can initiate developmental processes in the cell and exercise some control over their subsequent path. The action of each gene is influenced by the other genes with which it is associated, so that development and differentiation of the organism is normally closely integrated. Genes are themselves subject to change, or mutation, so that new genetic material can constantly arise from this source, but most of the variation between parents and progeny in outbreeding organisms is the result, not of gene mutation, but of the segregation and recombination of genes at meiosis. Although many of the genetic variations found among individuals which can freely interbreed may be controlled by single genes, it is now clear that many characters and especially those which vary quantitatively are controlled by swarms of genes. The importance of such polygenic systems in evolution has been discussed in detail by Mather (1943). The morphological and physiological properties of an organism are the particular expression of its genetic constitution in the environment in which it develops, and natural selection must tend to favour those individuals in which this expression (phenotype) is optimal. Characters controlled by balanced combinations of numerous genes can be main-

tained at their optimum if the polygenes are on the same chromosome and are closely linked so that the frequency of recombination is low. Stability is thus achieved, but at the same time different combinations of polygenes can be so balanced as to produce the same phenotype. Thus a group of apparently similar individuals which can interbreed can yet retain a store of variability and the speed of its release is controlled by linkage, so that recombination frequency is itself adaptive and subject to selection. Tightly linked groups permit a slow rate of release and this will give a degree of genetic flexibility and an insurance against changes in the environment.

Gradual shifts in the balance of the gene-complex through successive generations will occur under the pressure of selection and the spread of improved gene-complexes through a species will bring about its evolution. Any tendency for diffusion to be restricted will encourage the development of localised gene-complexes so that isolated populations, or groups of populations, will diverge as each population will become adapted to the special features of its environment more or less independently of the others. It is also possible for divergence to occur within a single breeding unit, or population, if selection changes from favouring the mean phenotype to favouring the two extremes; such a system of 'disruptive' selection has been demonstrated experimentally to cause divergence in artificial populations of the fruit fly, *Drosophila melanogaster*, if phenotypes with extremely high or low numbers of sternopleural bristles are constantly selected for breeding and the phenotypes with numbers about the mean for the whole population are rejected (Thoday, 1958).

In most natural systems which have been investigated some degree of isolation which limits the flow of genetic material has usually been demonstrated to exist or have existed.

In this respect geographical or ecological separation is widely recognised to be of profound importance. Many species of both plants and animals are distributed patchily in discrete colonies with the disjunctions determined by intervening areas which either do not offer favourable habitats, or from which the species is absent by historical accident. The extent to which there is contact between the colonies over a long period of time will depend on changes in the environment, as well as on the behaviour of the species concerned. It is clear from Ford's observations on the Meadow Brown Butterfly (*Maniola jurtina*) that apparently quite insignificant barriers, such as a strip of different vegetation a few hundred feet wide, may handicap the free flow of genes sufficiently to cause abrupt or, through several incomplete barriers, a gradual change in gene frequencies. Division of a species into separate populations which have little or no contact throughout long periods will favour their divergence by the independent adjustment of their gene-complex and gradual accumulation of numerous small genetic differences.

In each colony or group of colonies which form a breeding population, the gene-complexes which develop will depend partly on the original range of genetic material represented. The importance of this has been emphasised by Mayr and its effect is most readily recognised in colonies which have originated from a single individual. In the thistle, *Cirsium acaule*, for example, many of the isolated colonies on the periphery of the range of the species in England and Wales contain only one sex and show uniformity in various morphological features such as seed size and shape, whereas in south-east England where the species is common, populations include both female and hermaphrodite plants together and there is considerable genotypic morphological diversity within populations. Subsequent changes in the gene-complexes in an isolated population are probably most commonly shifts in balance under natural selection, and divergence of populations is then a consequence of differences in their environments. A striking example is afforded by the polymorphic species of snail, *Cepaea nemoralis*, which includes several varieties distinguished by the colour and banding of the shell. Cain and Sheppard have shown the frequency of the forms in each population is correlated with features of the habitat and have demonstrated that this arises through selection by studying the proportion of the colour varieties in the broken remains around stones used by thrushes (*Turdus ericetorum*) for breaking the snails when they eat them. Other unidentified selective agencies must, however, also be operating which maintain the polymorphism within each population. As it is extremely difficult to be certain that a feature has not direct or indirect selective value

to an organism, great caution is required in attributing divergence to chance loss and survival of a genes ('genetic drift') even in very small populations where such a process is plausible on mathematical grounds. In any case, where numerous genes affect a character, random fluctuation in the frequency of single alleles will be of little importance.

Differences between small isolated populations are particularly well-marked in the case of many uncommon species of which the present scattered localities are almost certainly fragments of a much wider and more continuous range in the Late- and early Post-Glacial period. The widely scattered populations of the small rockrose, *Helianthemum canum*, in Western Europe, for example, have been studied by Proctor, who has shown that they tend to be internally uniform but genetically distinct from each other in various morphological features. That this condition can arise as a result of divergence rather than of the disintegration of a previously variable population is suggested by the observation made by Kramer and Mertens on the populations of the terrestrial lizard, *Lacerta sicula*, which inhabit islands formed by progressive submergence of the Adriatic coast of Jugoslavia. The degree of genetic divergence of the isolated island populations from that of the mainland is positively correlated with the time that has elapsed since the separation of the island as measured by the depth of the channel, and negatively correlated with the size of the population.

When contact is re-established between previously isolated populations as a result of changes in their range, in many cases free interbreeding results in the submergence of the accumulated differences and the fusion of the populations is marked only by an increase in the variability of the combined population. This situation is of widespread occurrence in plants where large-scale changes in vegetation as a result of human interference have broken down ecological barriers and permitted the spread and mixing of previously more or less isolated populations. This situation must occur widely, but passes unrecognised where the accumulated differences are small. Where, however, the units have become sufficiently distinct to be given taxonomic status, or have on morphological grounds been regarded as distinct species, the process has been termed 'introgressive hybridisation' and many cases have been studied in detail.

The breakdown of geographic isolation has been described in *Centaurea* by Marsden-Jones and Turrill. Occasional introductions of the continental *C. jacea* into Britain are followed by hybridisation with the common British species (or subspecies) *C. nigra* and eventually pure *C. jacea* disappears and its former presence is marked only by increased variability in the surrounding members of the *C. nigra* population. Breakdown of ecological barriers has taken place in *Vaccinium* where the isolating mechanism varies geographically. On mountains *Vaccinium vitis-idaea* and *V. mytillus* grow mixed together but show a pronounced difference in flowering time, but at lower altitudes as, for instance, in the south Pennines, their flowering periods overlap and where they grow together hybrids occur which have been shown by Ritchie to backcross with their parents and thus permit gene-flow. Enclosure of woodland, in which both species and occasional hybrids are present, is followed by a great increase in the vigour of *V. mytillus*, which is normally heavily grazed, and suppression of *V. vitis-idaea*. Woods enclosed against sheep for longer periods contain pure populations of *V. mytillus*. As most of the moorland occupied by the two species at the present day has been derived from woodland it seems likely that ecological barriers previously separated the two. In spite of the ecological differences and clear-cut morphological distinctions between these two species, the hybrid successfully establishes itself on moorland and will suppress its parents.

When divergent populations meet in a habitat which has not been disturbed, the hybrids and their progeny are likely to be at a disadvantage as they possess an unbalanced combination of contributions from two highly integrated gene-complexes adapted for different ecological conditions. On this basis Dobzhansky has argued that the reduction in reproductive capacity which the formation of unsuccessful hybrids entails would be expected to give selective advantage to those genotypes where hybridisation is reduced or prevented and this should eventually eliminate hybridisation. Selection of genes which minimise hybridisation has been demonstrated in *Drosophila*. The development of genetic barriers to hybridisation would then be stimulated if there is some contact between populations and certainly pro-

longed isolation alone, as in the case, for instance, of the plane, *Platanus orientalis* and *P. occidentalis*, has not resulted in the prevention of hybridisation despite considerable morphological and ecological dissimilarity. Mechanisms which minimise or prevent hybridisation between closely related species include differences in mating or flowering time and structural modifications which influence mating preference in animals, or pollinator specificity in flowering plants, as is found in the two, otherwise interfertile, species of campion, *Silene alba* and *S. dioica*, which are respectively moth and bee pollinated. In many cases where there is often no physiological barrier to hybridisation when the sperm or pollen is artificially transferred, some reduction in the number of viable offspring ensues. Moreover, such hybrids, though themselves viable, may be largely or completely sterile and this is commonly a result of failure of chromosome pairing at meiosis. It is on this account also, that polyploids usually achieve isolation from their parents at a single step. Polyploids which behave as separate species occur widely in plants but are much rarer among animals although they occur in some hermaphrodite groups such, for example, as the earthworms (Lumbricidae). Successful polyploid species usually arise from the doubling of the combination of two chromosome sets which, even if derived from two parents of the same species are sufficiently different to permit chromosome pairing, as in a normal diploid species, to occur regularly at meiosis. Selection should favour those genotypes in which structural changes of the chromosomes, such as inversion and translocation of segments, increase the tendency for chromosomes to pair at meiosis and reduce the risk of the chromosomes being disordered in the gametes. Chromosome duplication increases the number of genes but apparently the balance of the gene-complex is retained. Some physiological, apart from morphological, distinction between polyploids and their parent species is usual and they commonly possess different geographical ranges and ecological preferences, which reinforce their isolation. This has been demonstrated by Heslop-Harrison in the case of the species of spotted orchid, where the diploid species, *Dactylorchis fuchsii*, occupies base-rich soils while the tetraploid *D. maculata* ssp. *ericetorum* occurs on moist, base-deficient moorland soils. The sterile triploid hybrid is generally restricted to habitats where the two conditions meet.

Both polyploid and aneuploid plants which have not established an ordered behaviour of chromosomes at meiosis may be successful and maintain themselves by adopting asexual means of reproduction but at the same time their evolutionary potentialities are restricted. Such apomictic 'species' behave in some respects like obligatorily self-fertilizing 'species' and possess strictly limited variability within each strain and are often highly specialised to their environment. It is clear that the concept of species based on population structure and gene-flow cannot be applied either to asexual or perpetually self-fertilising groups of organisms, so that they lie outside the present discussion.

Investigation of the genetical mechanisms of sexual organisms and the broad ecological factors which influence their population structure has demonstrated the mechanism in the small-scale evolutionary change, whose reality has been established by observation. It is true that the changes observed during the passage of less than a century are small when compared with the diversity of species, genera and families, but it is quite unnecessary to assume any other mechanism of evolution to account for these greater orders of differentiation than these same processes continued over far greater periods of time.

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TWENTY-FIVE YEARS OF T.V.A.

By Prof. W. B. FISHER

The original aims of the project, as stated in the Tennessee Valley Authority Act of Congress passed in May 1933 were first, control of the Tennessee river, which is the fourth longest in the United States, in order to reduce flooding and soil erosion; second, to develop river navigation; and third, insofar as could be achieved without prejudice to the first two, the supply of electric power by hydro and thermal generation. It was specifically laid down that the project should treat the entire Tennessee basin as a unit, with sponsorship and financial support from the Federal Government: and thus there have been what could be regarded as encroachments on, or abatements of State rights, chiefly obviously in Tennessee itself, but also to a small extent in Alabama, Georgia, Kentucky, Mississippi, North Carolina and West Virginia. There were political and psychological overtones in this intervention by a Federal agency within a region which forms part of the 'Southern States'; it was a Democratic party demonstration of methods and possibilities; it released a great deal of reformist energy which had been frustrated by years of economic depression; and it clearly marked one stage in the transition within America from the period of individualist capitalist enterprise toward the age of the planner and technocrat. These last items are mentioned since they have come to possess considerable importance at the present time.

The Tennessee basin has an average annual rainfall of 51 inches, with a sharp seasonal maximum occurring between January and March inclusive. During these three months some 40 per cent of total annual runoff occurs. This allows a reasonably simple control procedure, which in brief amounts to storage of winter floodwater in basin dams, followed by gradual release during summer and autumn, in order to maintain navigation levels and the supply of water for electricity generation. Minimum level in the reservoir basins is reached in December; and the precise levels in each barrage are oscillated deliberately by 1 to 2 ft. at intervals in order to eradicate mosquito larvae.

Altogether, there is a drop of 445 ft. in altitude between Knoxville at the head of navigation, and the junction of the Tennessee, Ohio and Mississippi rivers. Nine mainstream dams, together with twenty-two smaller barrages on tributary streams make up a total of thirty-one barrages, with a further seven planned. It should be emphasised that although damage by flooding has been very greatly reduced, it has not been entirely eradicated. The mainstreams do not now rise to a disastrous level, but flooding can still occur on minor creeks. This is because the damage involved may be insufficient to justify the cost of a barrage. In the light of bitter experience, most urban building is concentrated on bluffs and river terraces above normal flood level, and low-lying areas are left undeveloped as parks or open spaces, even though this may give a somewhat fragmented character to the pattern of urban building. Chattanooga City is a good example, with its lowest 30 ft. above normal river level largely unbuilt on except for wharves; and the effect is moreover of somewhat reduced importance in view of the extended site-pattern of most American towns, and the availability of transport. The year 1957 which saw the highest flood level for ninety years, was regarded as a major test of T.V.A. control methods; and in the event, flood damage was largely confined to tributary valleys.

Before 1933 the Tennessee river could dwindle to a series of sluggish pools during a very dry summer; and for much of the year it was not possible to count on more than 4 ft. of navigable water as far as Chattanooga, with only 1½ ft. beyond. Now there is a channel giving a minimum

of 9 ft. as far as Knoxville, some 650 miles upstream from the Ohio-Tennessee-Mississippi confluence. As a result, traffic by river has greatly increased: in fact, deadweight handled has grown by thirteenfold, and total movements have risen from 33 million ton-miles in 1933 to 2,100 million in 1957. More significantly, perhaps, this rate of increase in water-borne traffic is double that on the Missouri river, its nearest rival, and more than treble for U.S. waterways as a whole. The main items carried are: coal, grain, mineral ores (chiefly alumina and phosphates), and other agricultural products. Coal already accounts for 40 per cent of the total tonnage handled, and is becoming increasingly important. At a time when the consumption of coal is showing some levelling off in many industrialised areas of the world, the growing demand within the T.V.A. area is of considerable interest and significance. T.V.A. is in fact now the largest single consumer of coal within the United States.

Grain movements, on the other hand, have over the last few years shown a tendency to decline, owing in part to the growing diversification of agricultural areas further to the west, which are becoming distinctly less of a cereal 'belt', and now include mixed farming and market gardening, both of which use the fastest possible transport methods.

One factor in the decline of rail traffic in the U.S., which is such a pronounced feature at the present time, is the growth of inland waterway transportation using the Middle Western rivers; and, as we have seen, the Tennessee river is currently the fastest developing unit in the system. Great expectations have also been aroused by the St. Lawrence Seaway. Tennessee hopes that, as three-quarters of its river traffic is already from or to regions outside the T.V.A. area, there will be a considerable use of raw materials and semi-finished products from the Erie-Pennsylvania area, leading to the growth of the Tennessee Valley as an industrial zone. One suggestion is that by the end of the next decade, the coal traffic alone could reach an annual average of 25 million tons.

The T.V.A. Act authorised the construction and acquiring of both hydro and thermal power plant, chiefly to supply domestic and light industrial users. As well, there were two more important industrial consumers: the Aluminium Corporation of America's works at Thorpe, and the state munitions plant at Muscle Shoals, which produced synthetic nitrates. At first, chief developments were in the direction of generation by water-power, and great emphasis was laid on the provision of electricity in rural areas. Twenty-six years ago, 3 per cent only of farms had electricity; now the figure is 95 per cent, and one-half of all the homes in the U.S. that are heated principally by electricity are located within the T.V.A. area. Consumption of electricity per head is more than double the national average, owing to low cost of production and charges, which in 1958 were exactly half of the average price throughout the country.

With the Second World War, however, unforeseen factors entered in. The enormous demands for aluminium, nitrates and phosphorus led to expansion of the modest-sized pre-existing plants; but most of all, there arose the two Federal atomic sites at Oak Ridge and Paducah, Kentucky. These latter together now use just over half (51-53 per cent) of all the electric power available in the T.V.A. region; and the earlier conception of the role of power generation within the general T.V.A. framework has consequently been radically altered. In 1958 the relative importance of consumers was: Oak Ridge and Paducah 51 per cent, Municipalities (for domestic and light industrial users) 31 per cent, heavy industry 13 per cent, the Alcoa 3 per cent, and outside consumers 2 per cent. It would now seem that effective sources of hydro-electric power are almost fully developed; and in order to meet present needs (which are still increasing), T.V.A. has been forced to build thermal plants, which now supply 70 per cent of the total current generated.

This explains why T.V.A. is at the present time the largest unitary consumer of coal within the United States, drawing mainly on the fields of Kentucky, Tennessee and Illinois, and to a less extent on the Alabama and West Virginian fields, with 46 per cent of all coal used moving at least for part of its journey by waterway. Recent sharp increases in demands for power led the T.V.A. to plan a further series of thermal generating stations; and this has rapidly become an acute national issue. During 1958 the expediency and ethics of thermal plant building were hotly

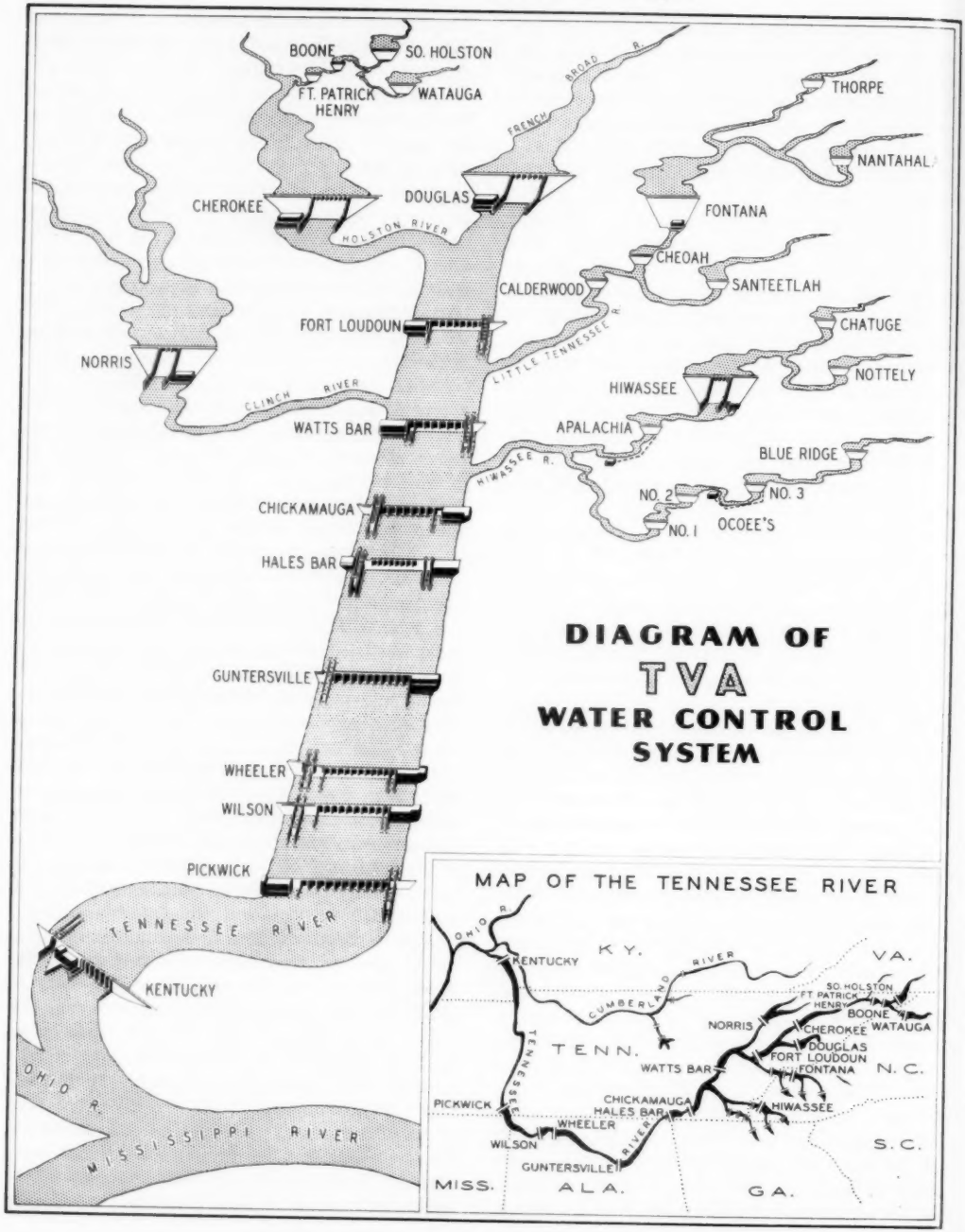


Fig. 1.—Diagram and map of the T.V.A. system.

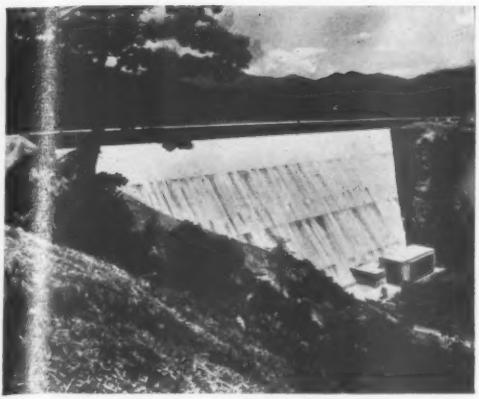


Fig. 2.—Fontana Dam, North Carolina, in the Great Smoky area. Height 480 feet; power installation 202,500 kw. capacity. (*Photograph by kind permission of the T.V.A., Knoxville, Tenn.*)

debated, even among T.V.A. administrative staffs. The original functions of T.V.A. as laid down in the Act of 1933 were, in the view of some, approaching total fulfilment—generation of power had been defined as definitely subsidiary to the two main aims which were river control and navigation, and the provision of public works at a time of economic crisis. To develop thermal generation further would be an intrusion into the rights of private industry, a misuse of governmental subsidies, and unfair competition through artificially depressed prices, arising from the fact that T.V.A. pays no Federal taxes (though it does in fact pay the equivalent of taxes to the seven states in which its area lies).

It is necessary to be explicit that there is no dispute over the actual need for more stations: it is simply a question of how these should be built—by T.V.A., or by private enterprise. Against the first view it is argued that no-one in 1933 could have foreseen the demands later to be made by Oak Ridge and Paducah; that it would be impossible to operate what is essentially a co-operative scheme by a mixture of state-owned and privately run plants; and that the low charges for power arise from the presence of the flood control barrages and from the economies of large-scale organisation—not from the favoured fiscal position of T.V.A., which according to some has its own financial burdens not felt by private industry. During a visit made by the writer to Tennessee, it was extremely interesting to hear vehement and widespread defence of the sanctity of private enterprise as a supplier of a public utility; and passions on this issue have risen high both in Knoxville and Washington.

With an administration in Washington that prefers to know not Franklin Roosevelt nor his New Deal, the political climate for an expansion of T.V.A. activities is at present far from being set fair. In an attempt to steer a diplomatic middle course, the T.V.A. administrators did not ask Congress to provide finance to build the new power-stations required, but instead, merely requested authority to raise this capital by mortgages upon T.V.A.'s own general resources. This proposal was either killed or shelved in Washington no fewer than five times: until, in August 1959, President Eisenhower somewhat surprised his own followers by authorising the proposals. In the meantime, stop-gap measures using present electricity revenues have been employed to finance development and these will, in the studiously moderate language of a T.V.A. pamphlet, 'minimise potential deficiencies' during 1960-62. There is at present about half-a-million dollars annual surplus of electricity revenue over production costs.

With the expansion of transport and fuel supplies there has been a marked development of general industry. Mention was made of the synthetic nitrate plant established for war purposes at Muscle Shoals in 1916: this also produces phosphorus. In peace-time the plant is turned over to making agricultural fertilisers, the use of which has quadrupled generally since 1946 in the North Central states of the U.S.A.—an indication of changes in farming methods but of which space does not allow discussion. Muscle Shoals not only acts as a public research and demonstration station for the use of nitrate and phosphate fertilisers—the only one of its kind in the U.S.—but also maintains smaller research and demonstration stations in thirty-four other states of the U.S. The electric furnace specially designed by T.V.A. has allowed economic use of low-grade phosphate ores which occur chiefly in Idaho, Montana, Utah, and Wyoming, and because of low current costs and water transport it is cheaper to move the

ores to Tennessee. Little need—or can—be said of the purely military side of T.V.A.'s chemical activities, in which at one time during the Second World War about half of the entire technical staff were employed. There are indications that besides explosives and incendiary weapons, lethal gases are also produced.

Manufacturing activities in private hands include the smelting of aluminium and ferro-alloys. Besides the Alcoa installations, there are other smelting plants, including one owned by the Ford Company. A general and petro-chemical industry is now located in various centres along the Tennessee river, with products that range from nylon to heavy industrial chemicals, carbide and abrasives. Processing of agricultural products—wheat, maize, sugar and oil seeds—is also important. Most of the industry located in Tennessee (one estimate is 90 per cent) has grown up since 1951, and a number of towns have consequently gained in status as manufacturing and marketing centres: Knoxville, Chattanooga, Decatur, Guntersville and Calvert City. The last two are somewhat extreme instances of the type of growth that has taken place. In 1948 Calvert City had 319 inhabitants. Within ten years more than twenty separate chemical and metallurgical plants have been built, and the population is now approaching 20,000.

Fig. 3.—Kentucky Dam, near the confluence of the Tennessee and Ohio–Mississippi rivers, impounds a sheet of water 184 miles long. By reducing the inflow of the Tennessee river, levels in the main Mississippi channel can be lowered by 4 feet. (*Photograph by kind permission of the T.V.A., Knoxville, Tenn.*)

Fig. 4.—A barge-tow of unusual size. All but two of the barges are carrying grain. (*Photograph by kind permission of the T.V.A., Knoxville, Tenn.*)

Guntersville was a small agricultural market town nearly a mile from the river until construction of a dam brought deep water round most of the town, which now occupies a peninsular site at the southermost bend of the Tennessee river. This has made it a good distribution point for the south-east of the T.V.A. area, and as well as functioning as an exchange and marketing centre, it has developed the following activities: car assembly, petrol distribution, milling, soya extraction, feed-cake making and paper and wood-pulp processing.

There was once a textile industry located on the Cumberland plateau and adjacent areas of the Great Valley, but this decayed because of competition from Alabama and New England. The character of present-day industries in Tennessee does not give much opening to female labour; and with the manufacture of synthetic fibres within the region, it is hoped that new opportunities will occur. The presence of this labour force together with low-cost power, water transport for fuel and raw materials, and a new geographical nodality suggest that there may be grounds for expecting further growth, leading to the emergence of a new industrial zone in a region which up to the last war was conspicuously lacking in these activities. Again, the possible benefits of the St. Lawrence Seaway are invoked by local businessmen: and a comparison could be developed with Stuttgart, where the Mercédes-Benz plant and its auxiliaries

rely on communications by water, a tradition of local cottage industry now long declined, and an enhanced geographical location as the commercial centre of a hitherto lightly regarded and predominantly rural region.

Briefer consideration may next be given to certain other developments which have come about as part of the T.V.A. scheme. Most of the Tennessee basin is forested: hardly anywhere is there less than 20 per cent of the area under woodland, and the average for the whole region is between 50–60 per cent. Three-quarters of this is hardwood, the rest softwood. Forest industries now employ some 50,000 workers, with the $125 million Bowater plant as the largest but by no means the only pulp-mill. Woodland resources could be even more productive. In many areas quality of trees is poor, and cutting exceeds replacement rates. A T.V.A. estimate suggests that forest production values could be trebled given more efficient methods of exploitation.

Malaria, spread by the *Anopheles quadrimaculatus* mosquito, was endemic in many areas before the T.V.A. project began: in a few parts, the average infection rate reached 76 per cent of the total population, and 40 per cent was fairly common. The extension of water areas by dam construction was an obvious potential danger, hence much attention was given to control measures. These, as has been stated, amount mainly to oscillation of water level by about 2 ft. during breeding seasons. The mosquito larvae are found

Fig. 5.—First steps in the reclamation of gully-eroded land: creation of a tree cover in an area almost devoid of soil. *(Photograph by kind permission of the T.V.A., Knoxville, Tenn.)*

in riparian waters to a depth of one foot; and hence by alternately stranding them without water, or submerging them so that large predatory fish can reach them, a very complete measure of control is attained. In fact no new case of malaria has been reported in the entire area since 1950.

The creation of large artificial lakes stocked with fish, and attention to closer afforestation in the catchment areas has produced a quite unlooked-for result—the growth of a tourist industry. For the Middle Westerner there is not a great deal of attractive countryside near at hand. Much of the Mississippi river area is turbid, humid and undistinguished, and the nearest tourist sea beaches are a thousand miles either east or west. Consequently the mountain and lake scenery, with keen air, clear water and full opportunity to indulge the national pastime of fishing now attracts a growing number of summer visitors who settle in chalets along the shores of the lakes. Permits are in force for over 40,000 boats, including a number of houseboats. To many Americans, life in the open is the best form of holiday, and the upland rim of the Tennessee basin, dominated by the Great Smoky Range, is coming to be a most useful vacation centre in its own right, or a half-way stage to the Atlantic coast.

A final, more intangible gain from T.V.A. has been the practical skills and confidence acquired in undertaking economic and sociological betterment through interference in the physical geography of a major river basin. Experience gained in Tennessee has led to similar experiments elsewhere—in fact, frequent references to T.V.A. methods in relation to the Jordan valley gave rise to the writer's personal interest in this topic—and one might say that there has arisen a T.V.A. mentality which is by no means confined to the United States. In this recital of development patterns, the impression may have been conveyed of uniform success and acceptance. This is not wholly true. The city of Memphis recently preferred to withdraw entirely from the T.V.A. power grid, and the warmth of discussion over financial and other issues indicate that some scepticism remains about T.V.A., and this not wholly for political reasons.

Nevertheless, despite criticism of the project as economically unsound, politically inspired, maintained by dubious book-keeping and over-publicised, there can be little, if any, questioning regarding the reality of the massive improvements, both physically and in the human regeneration of an area that, until the 1930's, ranked as one of the poorest in the Union. Comparison with nearby States of broadly similar geographical endowment will demonstrate the measure of advance brought about by T.V.A. planning. Much still however remains to be done, as, despite progress made, living standards are still below the national average.

For the geographer, there are further points of interest in T.V.A. The initiators of the project embarked on a scheme which had its main relation with specific engineering problems in hydraulics; and a minor aspect, the provision of hydro-electric power. Within twenty-five years they have been drawn into situations they would never at the outset have envisaged: a highly important share in the coal trade of the U.S.A., responsibilities for agronomical research in thirty-five states, and growing problems of tourist management. One can thus feel that T.V.A. provides for geographers a remarkable instance of the interdependence of elements which make up a regional environment: beginning with topography, dams and annual rainfall, we are ultimately brought to consider as essentially interlinked elements, for example the general space relationships,

Fig. 6.—The field on the left was equally as gullied some years ago as the field on the right. Erosion has been halted by the use of locally produced lime and phosphate fertilisers. (*Photograph by kind permission of the T.V.A., Knoxville, Tenn.*)

economic and political, of Canada; and the merits of private capitalist enterprise as against state planning.

Another highly important implication of the T.V.A. experiment is its relevance to future developments in the rest of the world. Whether we like it or not, large-scale transformation of the environment both physical and social will be essential if provision is to be made for rapidly growing human numbers. T.V.A. methods and approach may well therefore have future application within many other areas; though this is in no way to suggest that Tennessee has a monopoly of experience and initiative in such developments—similar schemes in other countries, notably Australia and the U.S.S.R. come quickly to mind. Planning and contrivance on a wider regional scale are likely to play an enhanced role in the future; and geographers ought to be concerned to demonstrate, for a particular area or project the extent and nature of inter-relations between various phenomena that make up a human and physical landscape. We particularly are trained as a fundamental approach to cultivate techniques of what de la Blache called 'the art of not dividing what Nature has put together'—in other words, to recognise relationships within an areal unit. The experience of T.V.A. administrators over the twenty-five years of their project has confirmed in a remarkably complete way the validity of this basic geographical premiss; and in consequence geographers will not be surprised to find in the latest published statement on T.V.A. aims and achievements the words 'a natural area', together with, as an introduction, the phrase 'T.V.A. makes geography the basis of human planning'.

THE WORLD LAND USE SURVEY

By Emeritus Professor L. DUDLEY STAMP, C.B.E.

In recent years the very rapid increase of world population has focused attention on two major problems: how many people can the world support and how best may the world's lands be used to provide the increasing population, on an increasing standard of living, with essential food and other necessities, if not luxuries of life. It has become apparent that many, indeed most, countries lack adequate information not only of their basic land resources but even of the existing use which they make of their land.

At the York Meeting of the British Association, Section E (Geography) devoted a whole day to a symposium of papers on Land Use Surveys designed to state the present position and some of the problems and to give an account of some work in progress. Mr. C. Board of the University of Cambridge presented a paper on 'Land Use in a South African borderland'. He was followed by Mr. Martin Brunt, Directorate of Overseas Surveys, Colonial Office, who described the land use vegetation survey of the Gambia. Mr. W. D. Clayton of the Herbarium, Kew, then gave an account of the conduct of a vegetation survey in Nigeria and its interpretation in terms of soil and land use. Mr. V. C. Robertson,* Technical Director, Hunting Technical Services Limited, then described a development study in Western Sudan which employed aerial photography and was designed to explore the possibilities for water conservation and irrigation development. The final invited contribution to the symposium came from Mr. R. G. Miller, Directorate of Overseas Surveys, Colonial Office, who reviewed the problems concerned with the making of surveys of forest resources. Two specially invited guests of the Association, Professor S. van Valkenburg (Clark University, U.S.A.) and Professor G. MacDonald Holmes (University of Sydney) contributed to the discussion.

* Prof. J. H. G. Lebon and Mr. V. C. Robertson presented a joint paper entitled 'Jebel Marra, Darfur, and its region' to the Royal Geographical Society on May 23, 1960. It is expected that this paper will be published in a forthcoming issue of the *Geographical Journal*.

Approximately every four years an international geographical congress is held under the auspices of the International Geographical Union. In the period between congresses work is carried out by a series of Commissions, appointed to investigate specific current problems. At the 16th Congress held at Lisbon in the spring of 1949 Prof. Samuel Van Valkenburg, Director of the Graduate School of Clark University, Worcester, Mass., brought forward a proposal for a Commission to investigate the possibility of making a world-wide inventory of land use. The Congress accepted the proposal and a Commission was formed with Prof. Van Valkenburg as Chairman and as Members Professors Hans Boesch (Zürich), Pierre Gourou (Paris and Brussels), Dudley Stamp (London) and the late Leo Waibel (then of Brazil). With the aid of a grant from UNESCO, the Commission met the following December 5–16 at Clark University and after hearing a number of expert witnesses, including the late Isaiah Bowman, and examining a mass of documentary material, drew up a unanimous report subsequently published with official texts in English, French and German.

It is one thing to draw up a report with recommendations, another to take practical steps for its implementation. Accordingly on January 1, 1951, London headquarters were established for a World Land Use Survey. Perhaps the title is too grandiose and misleading: what the survey set out to do was comparatively simple and modest. My Land Utilisation Survey of Britain which carried out its field work mainly in 1931–3 gathered so much material that the publication of 150 one-inch sheets and a report, county by county, in 93 parts, together with the final summary volume (*The Land of Britain: Its Use and Misuse*) was not completed till 1949, but it seemed a natural step for me to pass from my labours in

Britain to see what was possible on a world scale. I accordingly assumed responsibility for the initial pioneer work of the World Land Use Survey. We have had four main objectives.

The first has been to carry out experimental mapping, and especially to test the feasibility of using air photographs with limited ground control. Mr. John Callow and Mrs. Gillian Stone joined the staff and constructed maps of parts of Nyasaland and Kenya, of the island of Antigua (at the request of the Antigua Government) and of part of Mauritius (also at the request of the Government). This work proved a number of points. First, the fact that undoubtedly air photographs examined stereoscopically were ideal for the purpose. Second, that they revealed so much detail that it could scarcely be shown on the scale of 1:50,000. This means that maps on the 1:1,000,000 scale envisaged in the Commission Report would be highly generalised. The work confirmed the scheme of land classes proposed by the Commission with two emendations—it is not possible to separate 'used' and 'unused' rough grazing, and it is highly important to distinguish irrigated land. When my colleagues at the London School of Economics, Mr. R. R. Rawson and Dr. K. M. Sealy, undertook to organize a small team to examine 10,000 air photographs of Cyprus and prepare first a series of one-inch maps and then a generalised one on four miles to one inch, these points were confirmed.

The second objective, having satisfied ourselves of the soundness of our classification and of our *modus operandi*, was to persuade governments or other agencies all over the world to undertake these basic surveys of their land resources. The lessons we have tried to preach are that any planning for the future must start not from a blank sheet of paper but from the highly complex pattern of the moment, itself the result of centuries of the action and interaction of physical, historical, social and economic factors. With the mapping of the present-day pattern must go the attempt to isolate and evaluate these factors and to see what trends in development or change are taking place. Planning becomes so often the encouragement of a trend adjudged to be good (e.g. forest regeneration), the reversal of one believed to be bad (e.g. soil erosion). We judged it very important that countries should use our master key, adopt whatever *subdivisions* might locally be necessary, but not adopt *ad hoc* classifications which would prevent *their* results being compared with those from elsewhere. Nothing is more maddening than to find a complete absence of correlation between one country and its neighbour—which has been the case so frequently not only with land use but with botanical and soil surveys in the past. Whilst it is true that the trend of events, especially pressure of population, has turned the attention of countries all over the world to the need for surveys of present land use, the adoption of the simple principles advocated by the Commission has exceeded our wildest dreams. Perhaps as a broad statement it would not be far wrong to say that half the countries of the world now have surveys of this type in hand.

The third objective is a task which has devolved on me personally of acceding to invitations to visit different parts of the world and to discuss the problems involved. Suffice it to say that special journeys have been made for such conferences to Canada, the United States, including Alaska and Hawaii, Japan, Malaya, Burma, Pakistan (East and West), India, Iraq, Turkey, Sudan, Uganda, Ghana, Nigeria, South Africa, Brazil, Australia and New Zealand, as well as with world agencies like the Directorate of Overseas Surveys, United Nations, Food and Agricultural Organisation and UNESCO. Here it should be emphasised that a detailed land use survey is always recognised as one aspect only of the investigations needed, often stressing the urgent need for more climatological knowledge, fuller study of hydrogeology, detailed investigation of soils, a trace-element survey, and other special studies. If the approach through land use survey has a natural enemy or, shall we say, an opposite line of approach, it is that of the 'land capability survey', where land is classified according to its potential use on what so often seem to me highly subjective grounds.

The fourth objective has been to assist in a modest way publication of important results for which other channels are not immediately available. The World Land Use Survey *Monographs* started with the fine detailed map and monograph on Hong Kong by Dr. T. R. Tregear, then of the University of Hong Kong, followed by the very detailed History of the Evolution of the Land Use Pattern in Cyprus by Dr. D. Christodoulou. The

Series of *Occasional Papers* has been initiated with Dr. Monica Cole's studies of the Transvaal Lowveld.

What are the next stages? A land use survey is of the nature of a preliminary stocktaking. Even in the supposedly monotonous grassland of tropical east Africa no one could fail to be impressed by the present complexity of the pattern revealed. It should be made clear at once that, throughout, the World Land Use Survey emphasises both the use and the non-use of land: over the vast sparsely populated areas of the world it becomes a survey of natural and semi-natural vegetation, in fact a botanical or ecological survey. Every map is a challenge in its interpretation; every map emphasises how little we really know.

The World Land Use Survey presented a Report to the 17th International Geographical Congress at Washington in 1952, and a greatly extended one to the 18th Congress at Rio in 1956, when the Commission was reorganised. At the request of Prof. Van Valkenburg I became Chairman; its scope was made world-wide by the inclusion of Prof. Kostrowicki (Poland) and with Academician Gerassimov (U.S.S.R.) as corresponding member, and was further strengthened by the inclusion of Prof. Henri Gaussen (Toulouse). Prof. Gaussen has been extremely active in preparing and publishing vegetation maps of France and many parts of the world. In these he departs from the principles of the land use survey by using colours for vegetation which are chosen according to the dominant physical factors (such as rainfall and temperature) believed to be responsible for their main characters. This is, in fact, combining the factual first stage survey of the World Land Use Survey with part of the second stage of interpretation, and we remain in friendly disagreement within the Commission. This only serves to emphasise the range of unsolved problems, notably the relative importance of factors determining use or non-use of land. Some countries place a main emphasis on soil; others almost ignore soils as themselves a product of other physical factors—of climate, including microclimate, geological base material, slope and drainage. A new emphasis is being placed by many countries on details of land form—an application of geomorphology.

Although the cry is often and constantly to 'preserve the good agricultural lands' the definition of good, medium and poor lands, indeed the whole question of land classification, is exceedingly difficult. Even the measurement of actual output presents difficulties. I have given reasons elsewhere for using a Standard Nutrition Unit (SNU) of 1,000,000 Calories of farm production per annum pointing out that farmers think in terms of *annual* output, and that any crop, animal or vegetable, can be converted into Calorific values. Allowing 10 per cent loss in preparation and cooking, what the farmer produces is reduced to 900,000 Calories per annum available for consumption, or 2,460 Calories per day—a reasonable standard for maintenance of health on a world-wide basis. With this figure in mind we find that some diets—notably those with great reliance on meat and milk—are extravagant of land, and it may take 3–4 acres of land to produce one S.N.U., whereas one acre of intensively farmed rice land in Japan (with protein from beans and fish) will support 6–7 persons and, in one sense, the land is being used twenty times as 'efficiently'.

Still more difficult is the measurement of potential output or the 'carrying capacity' of land. What does seem to be emerging, however, is the world, as well as national, importance of inherently good agricultural lands—with adequate depth of soil, good texture and structure and well drained—which give a far greater return for a given expenditure on fertiliser than inherently poorer lands. Officially, according to the Ministry of Agriculture, Fisheries and Food, ten acres of hill grazing are rated as equivalent to one acre of average improved farm land. Bringing the finest market gardening land into the picture, it may well be that 20:1 is the sort of ranking between the English Fenlands and the Welsh Hills in potential productivity.

Certainly it is a field of study of immense world importance and one with innumerable problems awaiting investigation.

PLANT PARASITIC NEMATODES

Nematodes are for the most part small, worm-like creatures without segmentation and lacking in pigmentation so that they appear grey or white to the eye and are translucent under the microscope. Because of their elongated, thread-like or eel-like form, they are often known as threadworms if parasitic on animals, or as eelworms if free living on plant parasites.

By F. G. W. JONES *Rothamsted Experimental Station*

Plant nematology is the study of nematodes associated with or definitely harmful to plants. The relationship ranges from one that is purely secondary to obligate parasitism of the most advanced kind. All known plant-feeding nematodes possess a hollow mouth spear used for piercing cell walls. Most show little obvious modification in structure or life history (Fig. 1) but, in advanced parasites, the female tends to lose mobility, to become saccular and to degenerate into an egg-producing machine (Fig. 2). Parasitism is carried to its limit in the cyst-forming nematodes (Fig. 3). Here the body wall of the female becomes tanned and forms a protective envelope for the eggs which tend not to hatch unless stimulated by a substance given out by host roots.

Agricultural interest centres around those nematodes which thrive and multiply under intensive farming and devastate crops. Examples (Fig. 7) are stem eelworms and cyst-forming eelworms in temperate regions, the root knot eelworms in tropics and sub-tropics, the burrowing nematode in citrus, banana and pepper plantations, the nematode causing red ring disease of coconut and the various migratory nematodes in the south-eastern coastal plain of the U.S.A.

The first step in studying nematode diseases of plants is to isolate and describe the causal organism. Next come surveys of incidence and estimates of population levels that cause injury. Host range studies usually follow and only then can fundamental work on the host–parasite relationship begin. Control comes last and is based on a synthesis from information gained so far. Knowledge of chemical control by nematicides is in its infancy.

Scientific challenges occur at all stages in the study of plant nematodes. Many of the special difficulties arise from the microscopic size of nematodes and from the complexities of the soil and plant environments in which they live. Progress, as in other branches of biology, often depends on enlisting the aid of the physicist, the biochemist or the statistician, or in mastering and applying some of their techniques to particular problems. Five brief sections follow which illustrate some of the challenges which plant nematoloy makes to scientists.

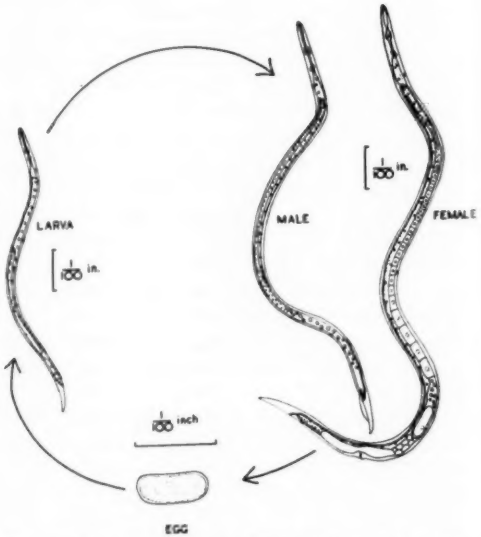


Fig. 1.—The stem eelworm *Ditylenchus dipsaci*, a plant parasitic nematode in which the life-cycle shows no obvious modification for parasitism.

Systematics

Marine nematodes live in a comparatively equable environment and exhibit a range of diversity far greater than those found on land, especially in the artificial and variable environment afforded by arable land. Interstitial life, which involves movement through the labyrinth of passages in the soil, between the folded leaves of buds or in the intercellular spaces of plants, does not favour the development of papillae or other

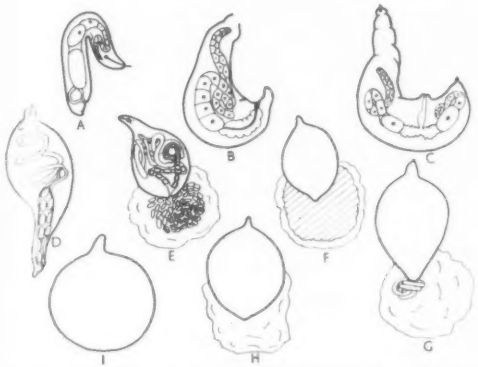


Fig. 2.—A group of plant parasitic nematodes showing progressive loss of mobility in the female. A: *Cacopaurus pestis* on roots of walnut; B: *Tylenchulus semipenetrans* on roots of citrus; C: *Rotylenchus reniformis* attacking the roots of various plants; D: *Nacobbus batatiformis* causing galls on roots of beet; E: *Meloidogyne* sp., the root-knot nematode causing galls on many plant roots; F: *Heterodera cruciferae*, the cabbage cyst-nematode attacking roots of brassicae; G: *H. schachtii*, the beet cyst-nematode; H: *H. avenae*, the cereal cyst-nematode; I: *H. rostochiensis*, the potato cyst-nematode.

A–E: Eggs laid externally, often in a gelatinous egg sac as in E. E–I: Successive stages in the loss of the egg sac. E and F have many eggs in the sac. G: Normally has a few (here shown with male in copulation) H: Sac without eggs, and I, sac absent or as vestige.

excrescences useful in identification which, therefore, depends to a large extent on internal structures that are few and translucent. Add to this microscopic size, a disinclination to stain and a tendency to distort unless carefully fixed and it is easy to see why soil and plant nematodes have been passed over by pure zoologists and naturalists and worked on mainly by applied scientists out of sheer necessity. Unlike insects, fishes, birds and mammals, nematodes have no popular appeal. Their identification is a tedious and meticulous matter involving long hours of preparation, microscopy and drawing. The highest powers of the microscope must constantly be used and only the best optical equipment is good enough. Up to the present, phase contrast, interference and fluorescent microscopy have not been greatly used. One difficulty is the high cost of this equipment which directors of research are reluctant to purchase until certain it can be put to good use. Consequently, few plant nematologists get the opportunity to explore the possibilities of advanced microscopy. Nematode systematics is a challenge scientifically: it is also a challenge to character. Because the delineation of closely allied species and the grouping of species and genera into larger taxa is often subjective, some who have long been in the subject, develop personal attachment to species and groups that they have created and bitterly resent newcomers with different ideas, a situation not unknown in other branches of systematic zoology.

Nematologists are few, and those abroad (apart from the United States of America) often work in isolation. For them a basic knowledge of systematics is essential, yet there are few places in Great Britain and the Commonwealth where this knowledge can be acquired. The teaching of nematologists is itself a challenge which most British universities seem loath to accept.

The Soil Phase

In all plant nematodes, the soil phase, however short and intermittent, is a vitally important link

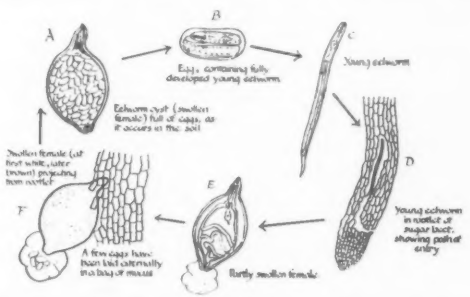

A
B
Eggs, containing fully developed young eelworm
C
Young eelworm
Eelworm cyst (swollen female) full of eggs, as it occurs in the soil
D
Young eelworm in rootlet of sugar beet, showing position of entry
E
Partly swollen female
F
A few eggs have been laid externally in a bag of mucus
Swollen female (at first white, later brown) projecting from rootlet

Fig. 3.—Life-cycle of the beet cyst-nematode. The male begins by enlarging like the female but, between stages D and E, it regains its worm-like form and escapes into the soil.

in the continuation of the species. Soil conditions affect the hatch of eggs and movement of larvae and so determine the intensity of attack. The literature is full of vague and conflicting statements about the relationship between soil conditions and nematode injury to crops. Recently progress has been made by isolating soil factors, principally the inter-related ones of structure, moisture and aeration. For this work the moisture characteristic has been used (Fig. 4). This relates the percentage moisture content to the force holding water within the pores, the force being measured in terms of suction in cm. of water. Simple relationships exist between this force, the relative humidity of the soil atmosphere, and the surface tension forces holding the water in the pores. The moisture characteristic can also be used to obtain an estimate of soil porosity. Experiments in sand of known particle size or soils of different kinds can be made in sintered glass funnels to which cysts, eggs, larvae or plants are added. Known suction forces can be applied through the sintered plate. The method is versatile and the funnels can be replaced by columns or plastic tubes of various dimensions. Maximum hatch and emergence from cysts is related to the point of inflection of the moisture characteristic which represents the point at which most of the pores are emptied of water but where considerable amounts still exist at points of contact of particles (Fig. 5). The most rapid movement occurs when most of the water has drained away under gravity. Speed of movement is also related to such factors as pore diameter, particle size, diameter and length of the eelworm and its relative activity. In movement over a surface or amongst water droplets, no progression occurs if the droplets are large. Forward speed increases as drop size diminishes and reaches a maximum when film thickness if from 2–5 μ (Fig. 6). These observations have a bearing on movement of worms in the larger pores of the soil labyrinth and also upon the movement of worms which ascend plants, such as the chrysanthemum eelworm (*Aphelenchoides ritzema-bosi*). Upward movement on plants probably cannot occur immediately after rain or heavy dew but becomes possible as the droplets dry and get smaller.

The work on the influence of physical factors in the soil environment is one aspect of Nematology in which the scientific challenge is being met with considerable success.

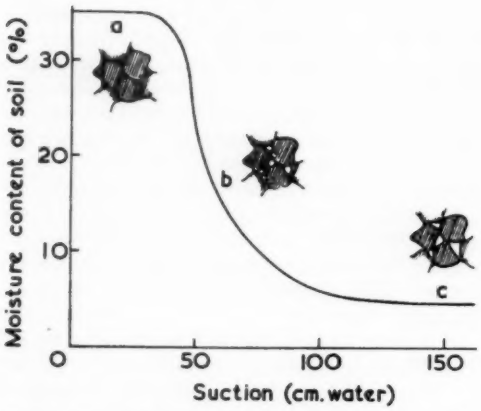


Fig. 4.—The moisture characteristic of a soil, i.e. the relationship between moisture content and the suction force withdrawing moisture. At low suctions the pores are full and at high suctions they are empty, permitting aeration. Most nematode activity occurs at suctions somewhat greater than those at the point of inflection of the curve (*Courtesy, R. D. Winslow*).

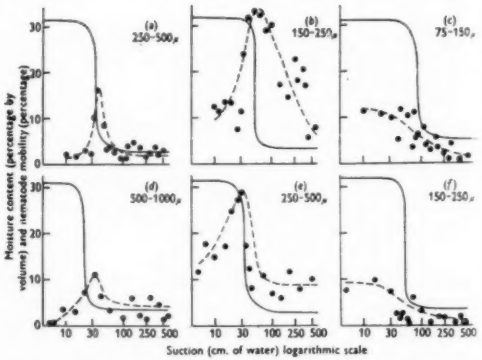


Fig. 5.—The relationship between suction force and nematode movement. Upper figures, beet eelworm; lower, stem eelworm. Maximum movement occurs at the point of inflexion of the moisture characteristic. The stem eelworm is larger and moves better when particle size is somewhat greater, 250–300μ rather than 150–250μ (*Courtesy, H. R. Wallace*).

The Plant Phase

Plant roots modify the soil environment. Substances exuded by them or derived from the death or injury of cells lead to great bacterial and fungal activity in the area immediately around the individual rootlets which is known as the rhizosphere and which can be regarded as an extension of the plant environment. Into the rhizosphere come many nematodes, predatory, saprobic and plant feeding. Internal parasites also must pass through it before penetrating the roots. Direct observation of the rhizosphere or of the internal plant environment is difficult but progress in observing activity in the former has been made by using culture chambers and cinematography.

Nematologists with different basic training approach the plant phase differently. Zoologists are primarily interested in nematodes as animals and tend to study water balance, oxygen requirements, feeding mechanisms, nutrition and behaviour, especially the response to stimuli causing attraction to roots and inducing feeding. Botanists interest themselves more in establishing pathogenicity, in studying plant responses to injury and possible transmission of pathogenic fungi and viruses by nematodes. Most nematologists are primarily plant pathologists (although this is not true of the few plant nematologists in Great Britain) and in consequence much less attention has been paid to plant nematodes as animals than as agents of disease. Apart from egg-hatching factors, the intriguing nature of which has absorbed a disproportionate time on their characterisation, so far without success, biochemical matters such as enzyme systems, composition of egg shell and cuticle, the nature of growth modifying substances in saliva have received little attention. There is, therefore, a wide subject open to the experimental zoologist who is prepared to take an interest in plant nematodes and much work still for plant pathologists as well as many opportunities for co-operative work between biologist and biochemist.

Host Range and Host–Parasite Relationships

To the farmer a knowledge of the host range of a pest is paramount. Early work is often limited in scope. A single population only may be tested against a range of crops and weeds to give what appear to be clear-cut results. Later, work with more populations and more plants, including different varieties of the same plants, shows a more complex picture, especially when developmental stages are followed in those plants which are unsatisfactory or marginal hosts. The existence of so-called biological races of plant nematodes morphologically indistinguishable but with different host ranges has been one of the features of this subject. Although some (e.g. cyst-forming nematodes) have been resolved into species others have not (e.g. the stem and bulb eelworms, the burrowing nematode). Both host and parasite vary, so that ability to develop and reproduce is best expressed as a frequency, e.g. when tested with an inoculum of Y individuals of the parasite, X reached maturity and reproduced on variety A of plant B. The ratio of X to Y is the frequency in question. For marginal hosts using small inocula, X will usually be

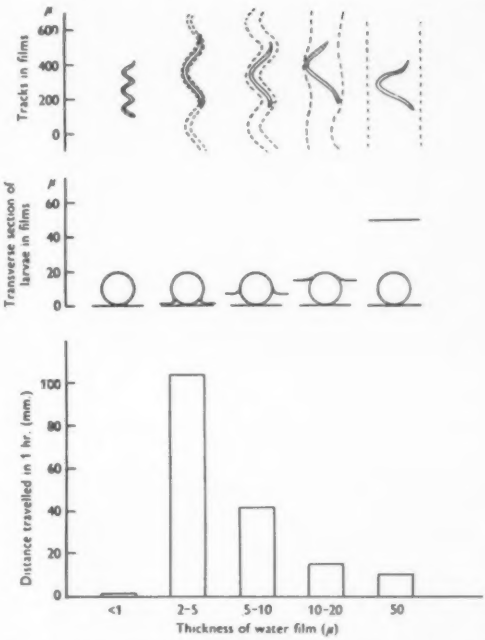


Fig. 6.—Movement of nematodes in surface films. Maximum movement occurs in films from 2–5μ thick (*Courtesy, H. R. Wallace*).

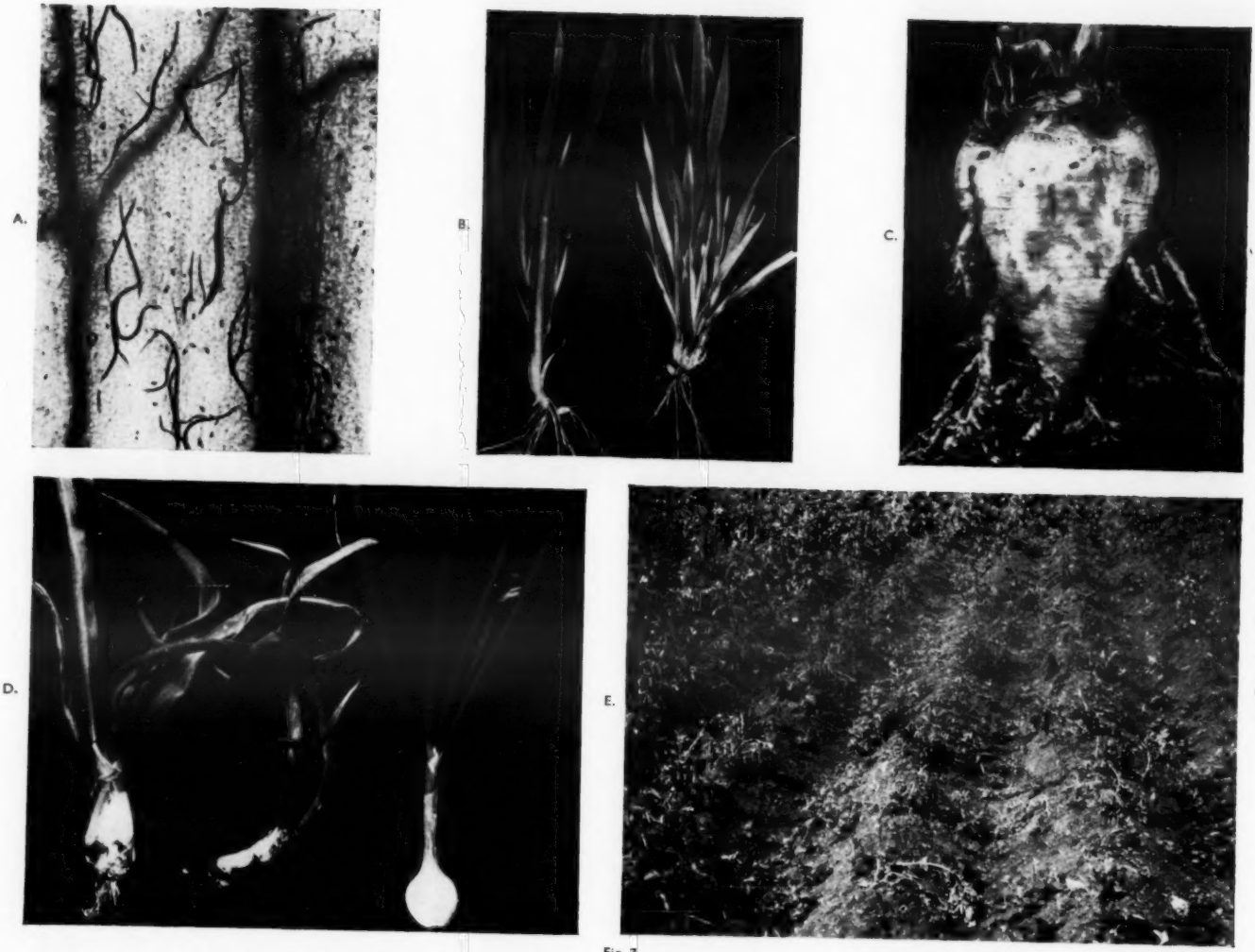


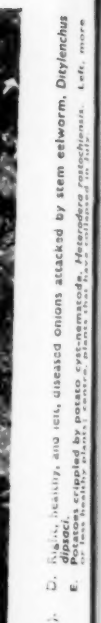
Fig. 7.

A. Nematodes, *Ditylenchus dipsaci* in onion leaf tissue. Stained with osmic acid (Courtesy, T. Goodey).
B. Left, healthy, and right, diseased oat plant attacked by stem eelworm, *Ditylenchus dipsaci*.
C. Root-knot nematode *Meloidogyne* sp., causing galls on sugar beet.
D. Right, healthy, and left, diseased onions attacked by stem eelworm, *Ditylenchus dipsaci*.
E. Potatoes crippled by potato cyst-nematode, *Heterodera rostochiensis*. Left, more or less healthy plants; centre, plants that have collapsed in July.

0 but for larger inocula, especially when drawn from several populations, X may be a small number. The ability of some individuals to develop on plants normally regarded as non-hosts poses intriguing questions, the answers to which are important in the breeding of resistant varieties and in unravelling the fundamentals of host–parasite relationships.

The problems posed by variability are well illustrated by recent work on resistance to potato root eelworm. Resistance found in some lines of *Solanum tuberosum* ssp. *andigena* is due to a single dominant gene H, which can readily be bred into domestic potato varieties. Early work gave consistent and promising results and hopes of obtaining resistant varieties within a short time ran high. Further tests, however, with a wider range of populations, showed that biotypes able to complete their development on plants possessing this type of resistance already existed in significant numbers in more than half of them. The two types of population tended to be grouped. Populations in which many individuals were able to develop on resistant plants were common in Lincolnshire and the Channel Isles whereas those in which few individuals developed were common in the peat fen soils in East Anglia and in Northern Ireland. Tests with the latter type of population also showed that the low frequency of resistance-breaking forms could be increased by selection to important levels after two to four generations. Similarly on the weed, black nightshade (*Solanum nigrum*), which is common in potato fields and is normally resistant, resistance-breaking biotypes can be found. The same is also true for *Solanum vernei*, another wild potato species that has been used in attempts to breed resistant varieties of commercial potato. The tobacco cyst nematode (*Heterodera tabacum*) found in one area in the U.S.A. may or may not prove to be a biotype of the potato root eelworm (*H. rostochiensis*). The situation is confused but at least it is clear that several different biotypes exist within potato root eelworm populations found in Great Britain and that these will complicate greatly the breeding of resistant varieties.

Biochemical aspects of host-parasite relationships have been little studied. Instances such as the above where the balance is controlled by a single gene would make an excellent starting point.



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Control

In Europe control of the important cyst-forming nematodes is achieved by crop rotation and by advice based on soil sampling, and is backed by considerable knowledge of host ranges and population changes with cropping. In the U.S.A. control is based on a combination of rotation and soil fumigation, and soil fumigation is much used against root-knot and migratory nematodes. Stem and bulb eelworms are controlled by crop rotation, eradication of weed hosts, fumigation of seed and the use of resistant varieties. Disinfestation of bulbs, runners, stools and nursery stock may sometimes be accomplished by hot water treatment, the time and temperature being adjusted to kill the nematodes with minimum injury to the plants. Although these cultural and physical methods are valuable, they are often inconvenient and not always adequate. Positive methods of chemical control at economic prices remain the ultimate goal.

Few satisfactory soil nematicides are known and there is nothing to match progress in modern insecticides or fungicides. Many *ad hoc* experiments are done each year with noxious chemicals, the results of which present a conflicting mixture of science and sales pressure. Three soil nematicides have stood the test of time: dichloropropene, ethylene dibromide and methyl bromide. Dibromo chloro propane and sodium methyl dithiocarbamate show considerable promise. Unfortunately all these compounds are over-expensive for most purposes under European conditions but may find uses for high value crops outdoors or under glass. Attention has recently been given to the incorporation of mercury compounds in soil all of which decompose to give elemental mercury vapour. For success solids must be thoroughly mixed with the soil, a process which usually requires more power than ordinary methods of seed-bed preparation and sometimes leads to loss of soil moisture or harm to soil structure.

Systemic phosphorus or other compounds have not so far proved very effective against nematodes feeding above or below ground. Parathion, which penetrates plant tissues locally but is not systemic, is useful as a spray against the chrysanthemum eelworm. Many substances are toxic to nematodes *in vitro* but are immobilised, detoxicated, destroyed or otherwise rendered ineffective when applied to

soil. The problems of incorporating nematicides in soil are greater than the corresponding problems for insecticides used against soil insects. Whereas many insects inhabit the soil surface or come near the surface to feed on seedlings and can be killed by surface applications or seed dressings, most nematodes inhabit the deeper regions of the soil which, because of its bulk (1000 tons/acre), acts as a considerable protective blanket.

Thoughts have recently turned to the possibilities of upsetting the host–parasite balance by applying substances to plants. The problems here are similar to those experienced with systemic poisons, namely absorption through foliage and the relatively slow downward transport to the root system. Where tried, resistance has not proved transmissible by grafting a resistant scion on a susceptible stock. Resistance appears to be a property of intact cells rather than a translocatable substance. However, some plants such as *Tagetes* and *Asparagus* contain principles in their roots that are highly toxic to nematodes and more plant nematicides may be found. Antibiotics and growth affecting or suppressing substances may also be tried. Some experiments in the U.S.A. are of interest. Growth of tobacco plants may be suppressed with maleic hydrazide which also suppresses the development of root-knot nematodes in their roots, apparently by preventing the formation of giant cells which are the normal host response to attack. Moreover plants in which elongation is just inhibited by a balancing dose of maleic hydrazide elongate when their roots are infested with nematodes. Evidently the nematodes produce or cause the production of plant growth factors.

A nematicidal dip or other treatment that would disinfest transplants or nursery stock would solve many problems, especially quarantine problems, for many potentially harmful nematodes are spread when their hosts are moved from one place to another. Methods of disinfesting bulbs, corms and tubers are also urgently needed.

Conclusion

What has been said above outlines the many and varied challenges which plant nematology makes to scientists at fundamental and practical levels. The complexity of soil and of plants as environments for nematodes introduces many confounding factors into experiments. These might be avoided by asceptic culture but, although several species of plant nematodes have been cultured successfully on their hosts, none so far have been cultured without them. Successful culture on artificial media would be a major achievement and is perhaps one of the greatest challenges to nematologists.

ECHOES from the Past

The uses of Magnetism

'Mr. Abraham delivered a Lecture on Magnetism, and particularly described several useful applications of this science, which he had employed for the advantage of the arts. He exhibited the model of a machine used for needle pointing, the labouring at which has been found so prejudicial to health, owing to the particles of steel inhaled during the process, that although the men were employed at it only six hours in the day, few ever attained the age of forty years, most dying at thirty or thirty-five, and several not surviving twenty-five. These deadly effects had been in a great measure obviated by Mr. Abraham's contrivance of placing several magnets around a mouth-piece, to attract the particles of steel as they came off in the process of grinding, or floated in the dusty atmosphere of the small apartments. This invention, for which the Society of Arts awarded their large gold medal, has not been so universally employed in the manufactories as its importance deserved, owing partly to the disinclination of the workmen to adopt methods which, by rendering their avocation less injurious to health, should lower the price of their labour.'

British Association, York, 1831.

* * *

The Passing World

'Exactly fifty years have passed since a President of the British Association last warned his audience of the danger of famine. Sir William Crookes was then alarmed at the prospective shortage of wheat. He produced evidence to support his conviction that England and all civilised nations stood "in deadly peril of not having enough to eat". But he qualified his gloomy forebodings by the statement that the chemist must come to the rescue of the threatened communities, and went on to discuss the possibility of the fixation of nitrogen. If that were achieved, the future, said Crookes, could take care of itself, and "in days to come when the demand may again overtake supply, we may safely leave our successors to grapple with the stupendous food problem." The chemist did come to the rescue, and the plant breeder too, though not quite in the way that Crookes imagined; and now the day has come when we must grapple again with the problem. . . .

. . . . . .

'I shall predict that unless the prevention of disease among plants and animals, and all other scientific problems of the supply of food, are studied on the same kind of scale, by men of similar calibre, as are the problems of human health, chaos and misery will result. Whatever new comforts and luxuries may be provided in future by the advance of physical science, it is on the development of the biological sciences that the peace and prosperity of the world will largely depend.'

Presidential Address, by Sir Henry Tizard, Brighton, 1948.

* * *

The Atmospheric Railway

'. . . Reference was then made to certain of the drawings and sections representing, drawn to the full size, an atmospheric apparatus equivalent in power to an ordinary locomotive engine, but occupying much less space. It is described to be a cast-iron pipe or tube of twelve inches in diameter, laid, in lengths like water-pipes, between the railway bars, and attached to the same cross-sleepers which support them; on the upper part of this tube

is a narrow longitudinal slot or opening, covered by a valve, the peculiar mode of opening and closing down and sealing whereof constitutes the ingenuity of the contrivance. The valve is a simple flap of leather, one edge of which is fastened down, so as to act as a hinge; the upper surface of the leather being plated in successive links with flat bar-iron, and the under surface also plated, but with links of a segmental form, to complete the inner periphery of the tube when the valve is closed down. In the tube moves a piston, made air-tight by one or more leather collars; at the end of the rod of this piston is a counter-weight, to keep the rod parallel to the axis of the tube: a connection is made (by one or more plates of boiler-iron of sufficient size and strength, and called the coulter) between the piston-rod and the perch of a leading carriage or guiding truck, in front of the train moving on the railway. In practice, the piston being in the tube, and at some little distance in advance of the opening of the valve, through which the coulter passes, a vacuum, more or less perfect, is made in that part of the tube in *front* of the piston by an air-exhausting-pump worked by a steam-engine or other stationary power; the air enters by the open valve, and presses at once and directly at the *back* of the piston; the opening through which the coulter passes is raised only for a few feet-length at a time, and the valve is rapidly closed down again, as the piston, carrying forward with it the train, moves on; and being closed, the edge of the valve-opening is hermetically sealed up, and the tube rendered air-tight by a composition of bees'-wax and tallow, varied in certain proportions, according to season and climate: this composition is laid at the valve-edge, in a groove, into which it is pressed by a copper slide, kept just warm by heated charcoal in an attached box. The whole of the mechanical arrangements of rollers, heater, etc., are very far from being complicated, not liable to get out of order, and easily adjusted when deranged; the operation being completely effected when the carriages travel at exceedingly high velocities, as has been repeatedly done leaving the tube ready to be again exhausted of its air, and allow the next following train to be impelled by the atmospheric pressure.

One leading characteristic of this new system is that of substituting stationary for locomotive power, and in this substitution the advantages will in many cases be great. . . . This stationary power is to be erected at long intervals on the line of railway, and may certainly be placed at three or four miles, and probably at five, or even six or seven miles apart, working the exhausting-pump, which will be connected by branches with the main tube lying between the rails.

'The air being drawn out by the pump, a certain amount of vacuum is produced in front of the piston, creating a corresponding pressure on the opposite side of it. . . . The measure of the power for producing motion is the product of the transverse sectional area of the tube in square inches, multiplied by the number of lbs. pressure due to the vacuum. . . . These representations were not based on theory only; they were the results of the working on a piece of experimental railway for the last two years and upwards on the West-London line at Wormwood Scrubs, only a few miles from the metropolis. The tube at this place is only nine inches diameter; but there will be a most complete practical demonstration on a larger scale shortly, on the opening of an extension of the Dublin and Kingstown railway to Dalkey, now constructing upon the atmospheric principle. . . . In entering into the question of the cost of the atmospheric railway, several tables were referred to, and it was distinctly and unreservedly stated that from £10,000 to £12,000 per mile was sufficient to construct a line on this principle and in most parts of any country . . . .

Extract from lecture by Prof. C. Vignoles, British Association, Manchester, 1842.

* * *

On a new Organic Compound containing Boron

'The authors exhibited a new body obtained by the action of zinc-ethyl on boracic ether, in which the whole of the oxygen in boracic acid is replaced by ethyl, $B(CH_5)_3$. This boric triethide is a colourless, mobile liquid, spontaneously inflammable. The authors are engaged in investigating the corresponding reaction on the ethers of carbonic, oxalic, and silicic acids.'

Dr. Frankland and B. Duppa, British Association, Oxford, 1860.

LOOKING AT science

Where are the Science Films?

It is generally accepted today that film has an important part to play both in presenting and obtaining information for scientific purposes. Something between 700 and 1,000 new films become available in Great Britain every year and many of these are either directly or indirectly concerned with subjects of scientific interest.

At its last six Annual Meetings the British Association has presented a selection of the world's best scientific films. Programmes screened throughout the week have included something like forty films each year, ranging over a wide variety of scientific subjects and made by film-makers in many countries using a variety of techniques.

Such films may be of help to the educationist in presenting some aspects of science to his students and may be of value to the scientist himself either by giving him a new perspective on some aspects of his own subject or by showing him the work of scientists in other fields. Special ciné techniques like cinemicrography, time lapse, or high-speed photography have made notable contributions to our scientific knowledge. One thinks, for example, of the work of the Americans and Japanese in the field of micro-organisms, with their beautiful studies of cell division or the behaviour of protozoa. One recalls some of the film studies of the Electrical Research Association into the behaviour of arcs and the application of this knowledge in the field of welding. Time lapse cinematic techniques have not only provided useful information for the specialist worker, but also have supplied beautiful and at times dramatic film material in popular presentations of science to the general audiences.

The ciné camera has become the valued tool of the biologist and engineer, the physicist and chemist, the zoologist and works study expert. There is a wealth of film material to be seen if only we know the sources from which it may be obtained. Nor are these always so very obvious. One would not immediately think, for example, of the British Transport Commission as a distributor of some remarkable nature films; or of the offices of a car showroom as the repository of one of the best films on some aspects of automation; *Encyclopaedia Britannica* are not generally known as sponsors of scientific films. The glossy film catalogue of a Public Relations Department may contain some unique scientific film material. The coloured cartoon which has been accepted as light entertainment at many meetings may, in fact, also be unique film teaching material.

We, therefore, list below some of the principal sources from which films of scientific interest may be obtained in this country. It must be emphasised that this list is by no means complete and that it is only intended to give a broad picture of the variety of sources from which scientific films may be obtained.

Some sources of Scientific Film

The following are some of the libraries which distribute scientific film. For details of many others readers are referred to the August and September 1959 issues of *Film User*, which list some 500 distributors, many of whom handle scientific films.

Australian News & Information Bureau, Australia House, Strand, W.C.2.

British Electrical Development Association, 2 Savoy Hill, W.C.2.

Boulton-Hawker Films, Hadleigh, Suffolk.

British Transport Films, 25 Savile Row, W.1.

British Film Institute, 164 Shaftesbury Avenue, W.C.2.
Central Film Library, Bromyard Avenue, London, W.3.
Contemporary Films, 14 Soho Square, W.1.
Esso Petroleum Company, Public Relations Department, 36 Queen Anne's Gate, S.W.1.
Foundation Film Library, Brooklands House, Weybridge, Surrey.
French Institute, Queensbury Place, S.W.7.
The Gas Council, Murdoch House, 1 Grosvenor Place, S.W.1.
Gateway Film Productions, 470 Green Lanes, Palmers Green, N.13.
GB Film Library, Aintree Road, Perivale, Greenford, Middx.
Imperial Chemical Industries, Imperial Chemical House, Millbank, S.W.1.
National Coal Board, Hobart House, Grosvenor Place, S.W.1.
New Zealand Film Library, John Adam Street, Adelphi, W.C.2.
Petroleum Films Bureau, 29 New Bond Street, W.1.
Plato Films, 18 Greek Street, W.1.
Sound-Services, Wilton Crescent, Merton Park, S.W.19.
United Kingdom Atomic Energy Authority, Public Relations Department, 11 Charles II St., S.W.1.
Unilever Limited, Unilever House, Blackfriars, E.C.4.

BOOKS

Science as History. By Heinz Gartmann. (Hodder & Stoughton.) 25s.

Heinz Gartmann, a German engineer, has succeeded admirably in his aim of writing for the layman the story of man's technological progress from steam engine to satellite. It is a plain, comprehensive, eminently readable tale, made doubly interesting by being told against a background of human struggle and conflict. The story is interwoven with the struggle between vision and blindness, the conflict of indomitable spirit and stagnation, and the clash between those who pursue and those who fear change. Drama keeps pace with the unceasing persistence of man to better himself.

This makes fascinating reading for those, and there should be many, who take the opportunity of looking back over the centuries with the author. The genius of James Watt, who arrived just in time to send steam power coursing through the arteries of the new industries of the Industrial Revolution, 'multiplied the power of men' to the accompaniment of cries of 'Down with the fire engine!' Gloomy prophecies greeted Stephenson's vision of the railway, but his 'absurd plan' was so successful that when the 1851 Exhibition opened the population came by train. The age old dream of man, to fly like the birds, was fulfilled through knowledge, persistence and courage, an epic achievement, followed by the magic of radio, radar and television. The story gathers momentum as the author relates how man prised open the atom and gained a new source of energy, created fully automatic machines and electronic 'brains', and ends with an exciting account of penetration into space, and the race to the stars. Truth is stranger than fiction, even space fiction.

'Nature has a weak side if only we can find it out,' said James Watt. The scientist finds out about nature and the technologist gives the findings a practical and useful shape. The story told by Heinz Gartmann keeps this interplay between the scientist and the technologist well in focus and, without overloading the detail, enables the reader to follow the successive achievements that have created our modern technological world, and to understand how they were accomplished.

This is not a text-book, but a story worth reading by young scientists and engineers, and by older practised hands who have been too busy with their particular trees to take a look at the forest. The text is illustrated by a wealth of photographs and drawings, and a useful bibliography is provided. A word of praise is due to the translator, Alan G. Readett.

SIR BEN LOCKSPEISER, K.C.B., F.R.S.

About Chemistry. By Magnus Pyke. 220 pp. (Oliver & Boyd, Edinburgh, 1959.) 18*s*.

Dr. Magnus Pyke is always worth reading or listening to on the radio, and many scientists as well as non-scientists must have read with pleasure *Nothing Like Science*.

The present volume is designed to help the layman to understand what chemistry is about, and how it is that man has been able to collect the logical facts and turn them to practical use. It aims rather to show how the chemist thinks and why he performs particular operations than to give a comprehensive encyclopaedic treatment of the majority of substances which the layman is likely to meet. This permits Dr. Pyke to pay attention to such important subjects as the mechanism by which glucose is used as fuel in the human body and how DNA enables the nucleus of living cells to control heredity. Such concentration on the fundamentals (with enough introductory and background material to enable the layman to understand) far more than compensates for some of the minor points on which improvement might have been desired.

The layman is likely to read this book—in which there are a large number of flashes of wit and insight—with enjoyment and profit, but he will, of course, have to be prepared to work.

K. HUTTON

Science in Industry: Policy for Progress. By C. F. Carter & B. R. Williams. (Oxford University Press, 1959). 186 pp., 21*s*.

This book is the third in a series of reports written for the Science and Industry Committee. The first of these was mainly concerned with analysing the problems of applying science to industry. The second dealt with the special topic of investment in relation to technical progress. The third contains the authors' recommendations for action arising out of their previous analyses.

These recommendations, which are both numerous and detailed, are tidily summarised in the final chapter with reference to the earlier pages in which they are more fully discussed; this is splendidly convenient for both reader and reviewer. It is not to be expected in such a controversial and unscientific subject that their suggestions will find universal approval, but no one can doubt their value as a simulus to further thinking as well as to positive action in many cases.

The book is arranged in two parts under the headings 'Action by Industry' and 'Action by Government'. In Part I, industry is exhorted to look around for ideas and possibilities to exploit. This is in line with customary thinking about industrial research in which science comes first to produce new knowledge and ideas, and their application to industry appears as a consequential problem. An alternative approach is for a company or industry to consider what are the technical problems that they are going to have to face within the next five to ten years and then bring in the resources and methods of science to solve them in good time. Views may differ about these two approaches, but the absence of any reference to the second in the recommendations calls for comment particularly in view of the attention the authors have given to the small firm for whom the question of survival in the next five to ten years must often loom large.

This part will give any managing director with a will to look to the future some definite ideas as to what he should do, including a programme of analysis to apply to his company. It does not tell him how to acquire that will. Is this a psychomedical problem, or can it be solved by having on his board, colleagues with the right outlook?

In Part II the authors give details of the 'great record' of the Government in the encouragement of science. They doubt, however, if it can be said that a firm Government policy on the application of science really exists, and proceed to make suggestions under the headings of aid for research and development, education, taxation, credit policy, tariffs and protection, and conclude with a chapter on restrictive practices. This part will no doubt already have been read by the principal civil servants concerned. Industrialists should also read it to get a clear idea of what is and *what is not* a governmental responsibility.

Readers of the first two volumes will need no exhortation to read this book. All who have the technical progress of British industry at heart will find it full of interesting thoughts and observations and, as already indicated, easy to read. This is a worthy finale to an excellent trio.

CHARLES GOODEVE

Other Books Received

The Chemicals of Life. By Isaac Asimov. (G. Bell & Sons Ltd.) 12*s*. 6*d*.

The Physicist's Conception of Nature. By W. Heisenberg. (Hutchinson.) 16*s*. 0*d*.

Atomic Energy in the Soviet Union. By Arnold Kramish. (Stanford University Press.) 27*s*. 6*d*.

Beekeeping in the Tropics. By Francis G. Smith. (Longmans.) 45*s*.

Sir Mortimer Wheeler. By Ronald Clark. (Phoenix House.) 8*s*. 6*d*.

The Scattering and Diffraction of Waves. By R. W. P. King and Tai Tsun Wu. (Oxford University Press.) 32*s*. 6*d*.

The Theory and Design of Inductance Coils. By V. G. Welsby. (Macdonald & Co.) 30*s*.

Transformers and Generators for Power Systems. By R. Langlois-Berthelot. (Macdonald & Co.) 65*s*.

The Sciences were never at War. By Gavin de Beer. (Thomas Nelson & Sons.) 30*s*.

Mathematics in Western Culture. By Morris Kline. (Scientific Book Club.)

Human Potentialities. By Gardner Murphy. (Allen & Unwin Ltd.) 25*s*.

Understanding Weather. By O. G. Sutton. (Penguin Books.) 3*s*. 6*d*.

Exploration of the Solar System. By F. Godwin. (Chapman & Hall.) 35*s*.

The Jaws and Teeth of Primates. By Warwick James. (Pitman Medical Publishing Co. Ltd.) 105*s*.

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